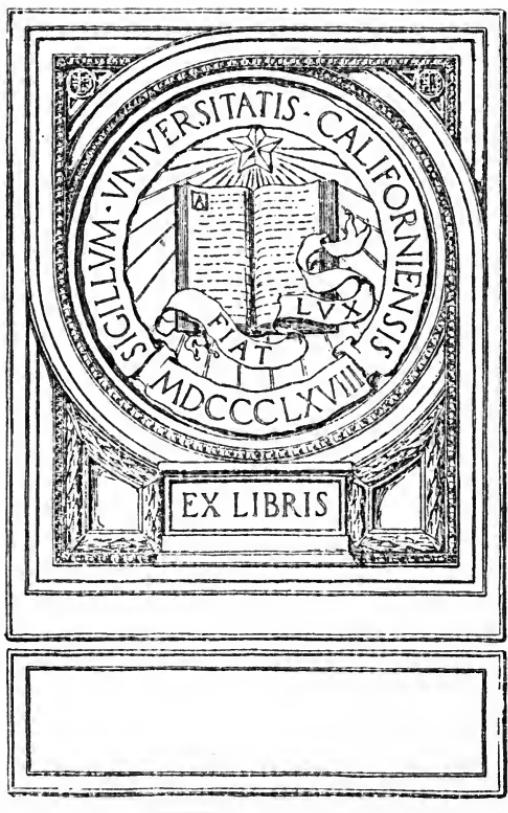


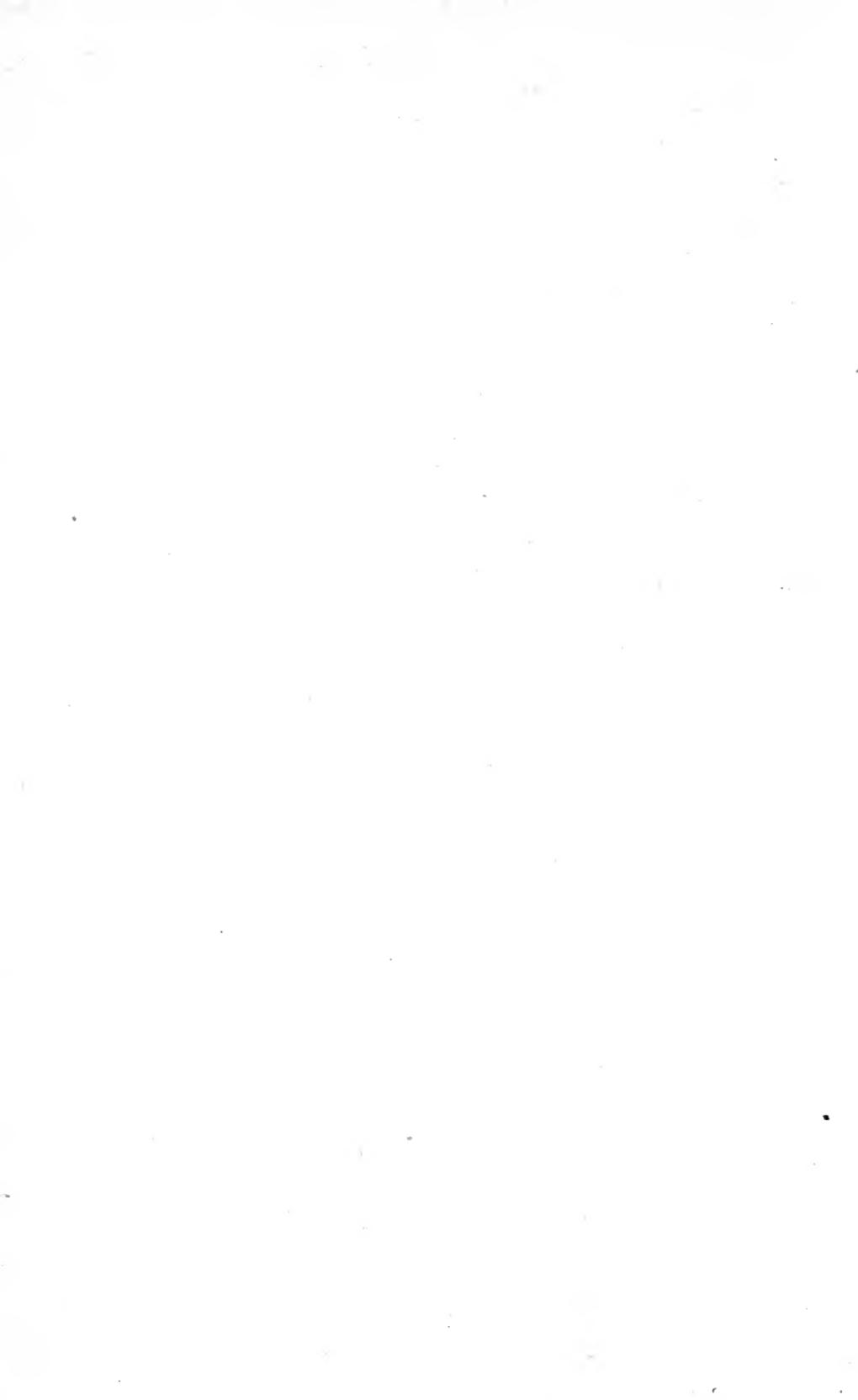
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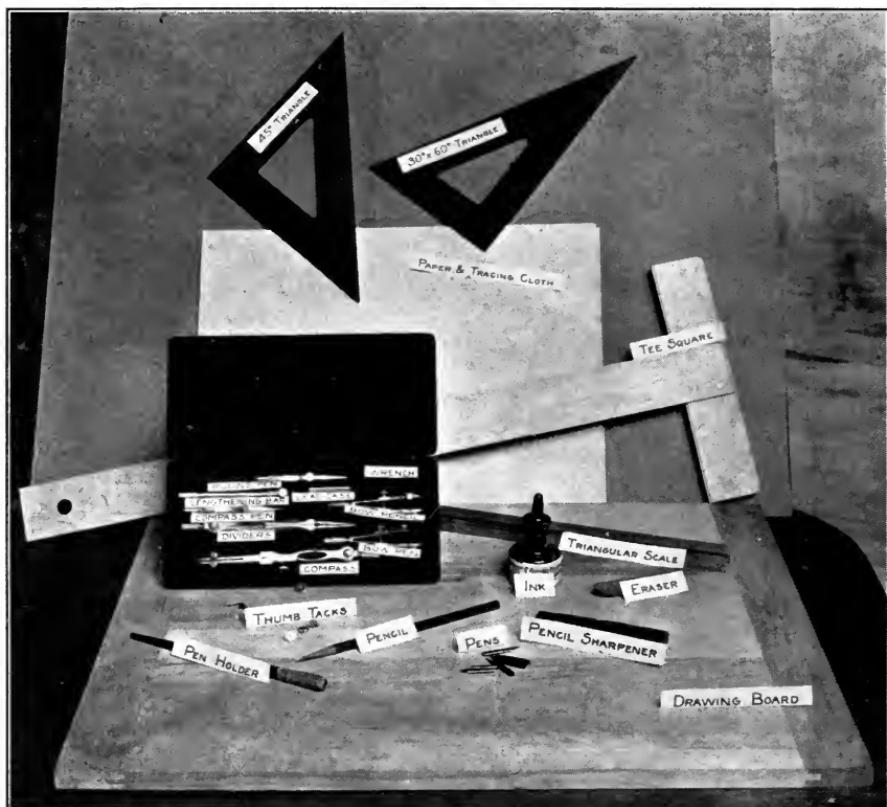
MACHINE DRAWING

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Frontispiece.

INDUSTRIAL EDUCATION SERIES

MACHINE DRAWING

PREPARED IN THE
EXTENSION DIVISION OF
THE UNIVERSITY OF WISCONSIN

BY

RALPH W. HILLS

INSTRUCTOR IN MECHANICAL DRAWING IN THE
UNIVERSITY EXTENSION DIVISION

FIRST EDITION

SECOND IMPRESSION



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PREFACE

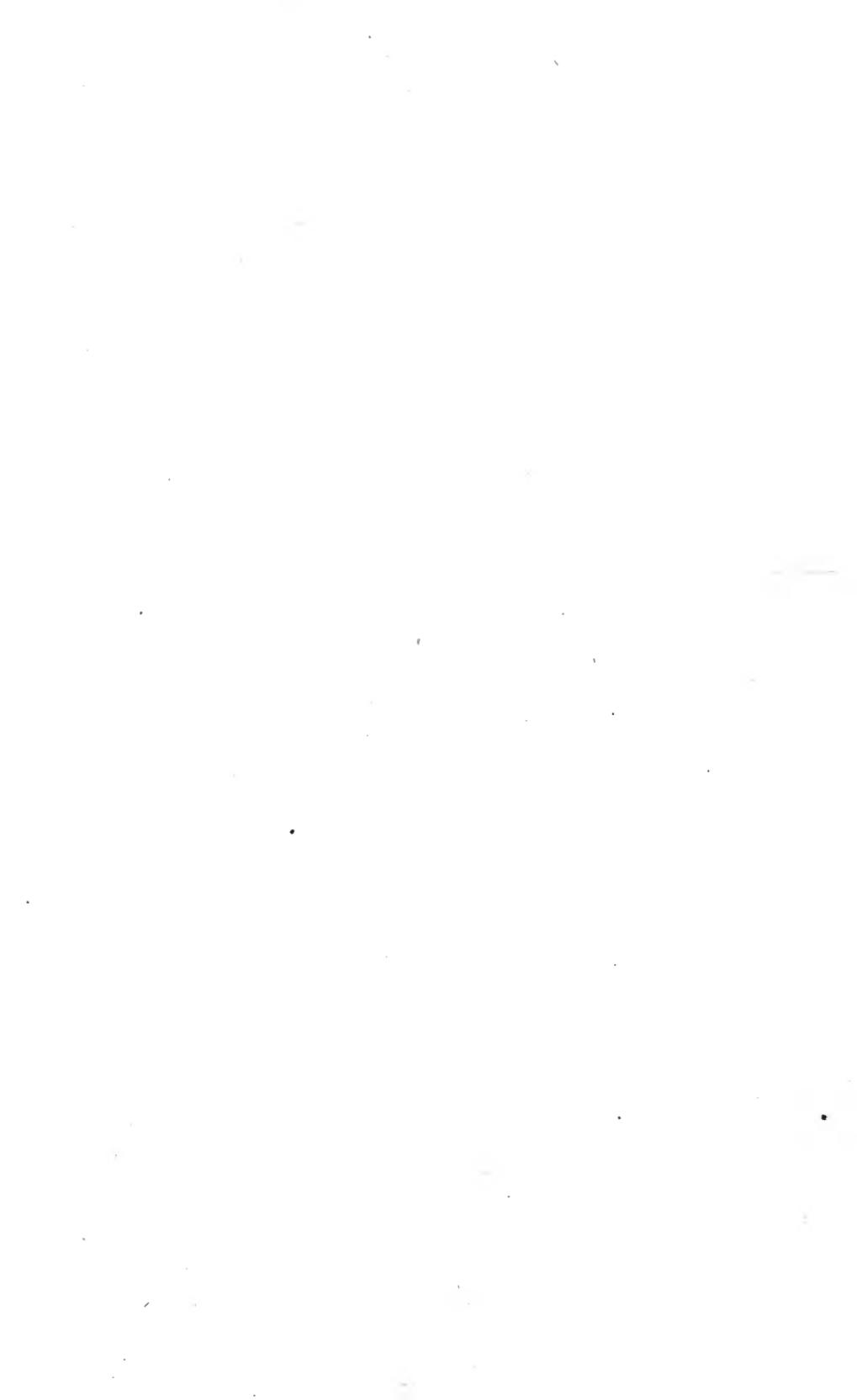
This book aims to teach the fundamental principles of mechanical drawing to men who wish to become draftsmen, or who for any other reason wish to acquire a working knowledge of the subject as practiced in the best drafting offices. *The material in this volume is the first half of the instruction papers in Machine Drawing, as developed and used by the Extension Division of the University of Wisconsin.* Part of the material has been taken from Woolley and Meredith's "Shop Sketching," of the University Extension Division series. *The second volume, Advanced Machine Drawing, will be largely devoted to the applications of machine drawing to the more specialized lines of work, such as gearing, isometric, cabinet, and other special methods of projection, electrical, structural, and piping conventions, and advanced problems in detail and assembly drawings of complete machines, sketching, intersections and developments, and sheet metal pattern drawing.*

In order to secure the interest of the student at the outset, working drawings are made by the student from the very beginning. The text and the problems have been carefully prepared and arranged so as to develop speed, accuracy, neatness, and a knowledge of the best drafting room practice. Believing that draftsmen should be able to make neat, clear, comprehensive, freehand sketches of machine parts, the author has introduced a chapter on technical sketching. In addition to being suitable for home study this book is also adapted as a text for trade, industrial and continuation schools.

The author desires to acknowledge his indebtedness to Mr. Earle B. Norris, Associate Professor of Mechanical Engineering, University of Wisconsin, for a careful reading of the proof, for checking the illustrations, and for many valuable criticisms and suggestions; and to Mr. Joseph W. L. Hale, of the Department of University Extension, Massachusetts Board of Education, for valuable suggestions.

R. W. H.

MADISON, WIS.,
June 16, 1917.



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INSTRUMENTS AND MATERIALS

The following equipment of instruments and materials, as shown in the frontispiece, is needed for carrying out the course of study outlined in this text:

1 set drawing instruments including:

- 6-in. compasses with detachable pencil and pen points and lengthening bar.
- 6-in. plain or hairspring dividers.
- 3½-in. bow dividers.
- 3½-in. bow pencil.
- 3½-in. bow pen.
- 5½-in. ruling pen.
- Box of leads.
- 8-in. 45° triangle.
- 10-in. 30° × 60° triangle.
- Architect's 12-in. triangular scale.
- Bottle waterproof black ink.
- 1 doz. thumb tacks.
- Penholder.
- Ball pointed pens.
- 2H drawing pencil.
- 4H drawing pencil.
- 20-in. × 24½-in. drawing board.
- 24-in. T-square.
- Combination pencil-and-ink eraser.
- Smooth file or block of sandpaper.
- 18 sheets drawing paper, 12 in. × 18 in.
- 6 sheets tracing cloth, 12 in. × 18 in.



MACHINE DRAWING

CHAPTER I

PRINCIPLES OF MECHANICAL DRAWING

ASSIGNMENT 1

1. Projections.—The principle of projections is the basis of mechanical drawing and must be thoroughly understood in order to read a mechanical drawing or to make one.

In making a mechanical drawing of any object, a draftsman deals with one face at a time, and makes separate drawings or views showing how the different sides or faces look. Thus we sometimes make as many *different* drawings or views of an object

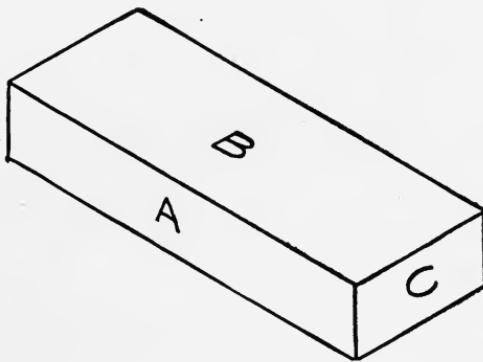


FIG. 1.

as the piece has *different* sides. Each view is made as if the draftsman were looking squarely at the particular side he is drawing. In Fig. 1 is shown a picture of an oilstone, such as might be made by an artist or a photographer. Looking toward the corner, as in this figure, we see three faces, the side *A*, the end *C*, and the top *B*. Fig. 2 shows a mechanical drawing of this same oilstone. Notice that the stone has its three different faces shown by the three views *A*, *B*, and *C*. In all there are six faces but, since the two ends are alike, and likewise the two

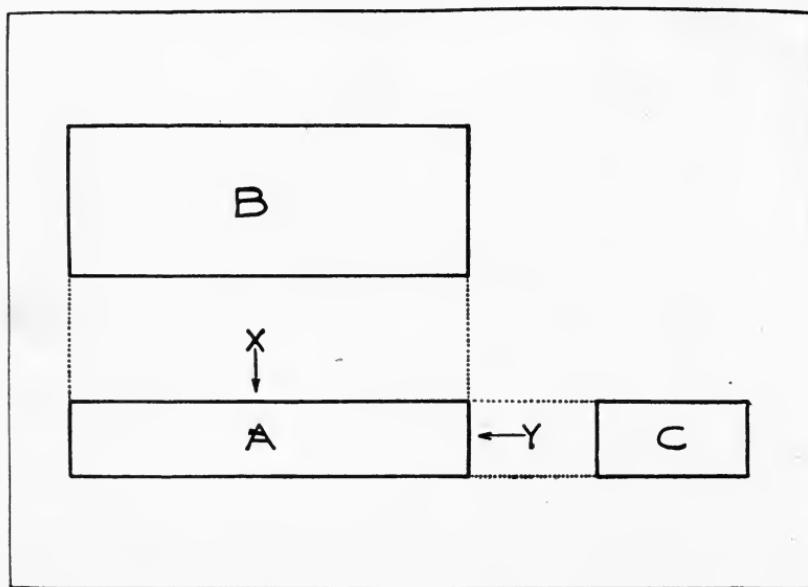


FIG. 2.

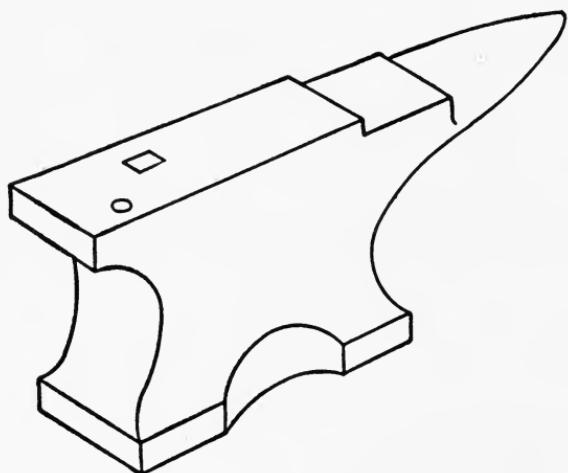


FIG. 3.

sides, and the top and bottom, it is necessary to show only the three *different* faces. Each view is a picture of one side as we would see it if the stone were held squarely in front of, and on a level with, the eye.

In making these views showing the different sides of any object, they should be placed in such a way as to show how they are related to each other in their position on the object. This is done by the principle of projection as follows: Referring to Fig. 2, notice that the top view *B* is placed directly above the side view *A*, so that the edges of *B* are on the same line as those

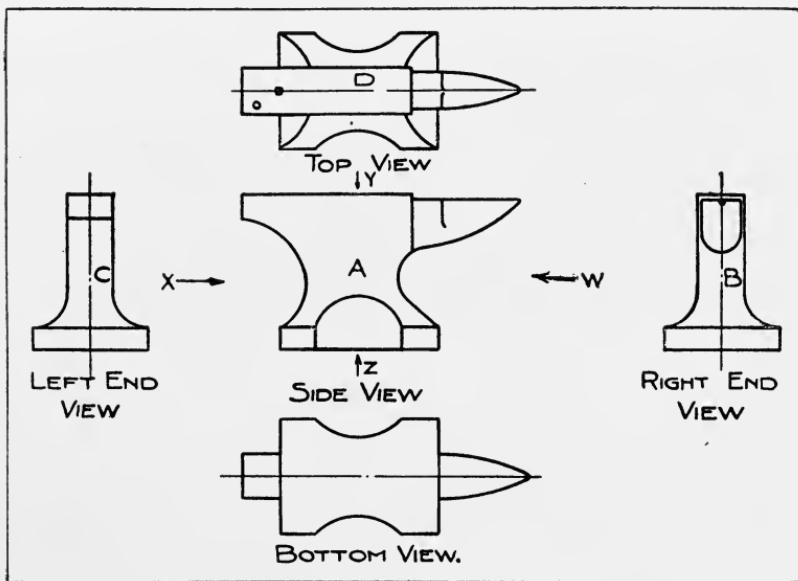


FIG. 4.

of *A*, as shown by the dotted lines. Also, end view *C* is directly in line with *A*. This is the principle of projection. In other words, the length of *A* is "projected" directly upward to form the length of *B* and the height of *A* is "projected" to the right to form the height of *C*. The dotted lines indicate the position of the straight edge in laying out the work, and show the relations between the sizes and positions of the views.

Fig. 3 shows a picture of an anvil. Fig. 4 shows the complete mechanical drawing of this anvil with the correct names of the different possible views that might be shown. As a general rule, we follow this grouping: In the center we place the side view

which shows the object set up in its natural position before the eye, and project the other views from it, placing the top view above, the bottom view below, the right-end view at the right, and the left-end view at the left.

The views of an object which show it set up before the eye in its natural position are sometimes called *elevations* and are further designated as *front*, *side*, or *end elevations*. The top view, obtained by looking down upon an object, is sometimes called the *plan*. The names which we give to the elevation views vary with different objects and different people. Usually we have two elevations given in a mechanical drawing, but people look at things differently and the view that some people would

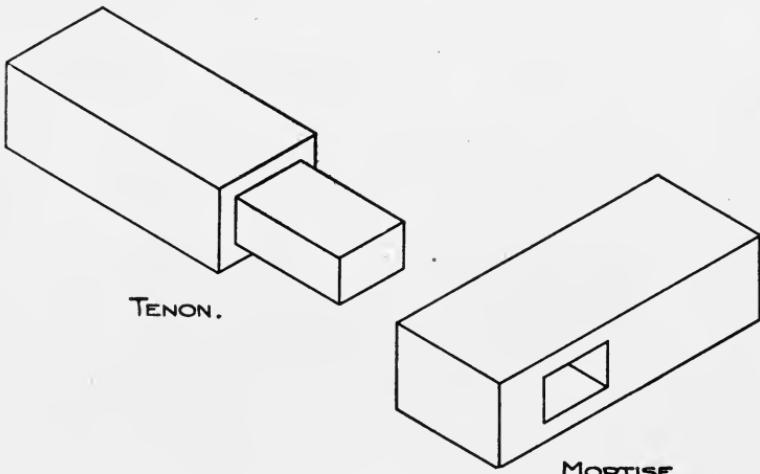


FIG. 5.

call a front view others might consider a side view. So we might have *front* and *side* views, or *front* and *end* views, or in the case of any object that does not have any particular face that could be called the front, we might call the views the *end* and *side* views.

Note Carefully.—We seldom need more than two or three views of a piece in order to show it. Generally a top, a side, and an end view are all that are necessary. It is only with very irregular objects like the anvil that we need as many as five views.

2. Relations Between Views.—Fig. 5 shows a sketch in one view of two blocks of wood which are formed so that they may be joined together with a mortise-and-tenon joint. A mechanical drawing of the tenon is shown in Fig. 6. Three views are shown,

namely, the side view *AB*, the top view *CD*, and the right-end view *EF*. The right-end view is shown rather than the left-end view because the form of the block and also of the tenon are shown in the right-end view. The surface *A* in the side view is shown in the other two views by the lines *a*. The surface *B* in the side view is represented by the lines *b* in the other two views. The student should check over the rest of the drawing with the aid of the letters so as to see just what each line in one view represents in the other views. The capital letters are used to

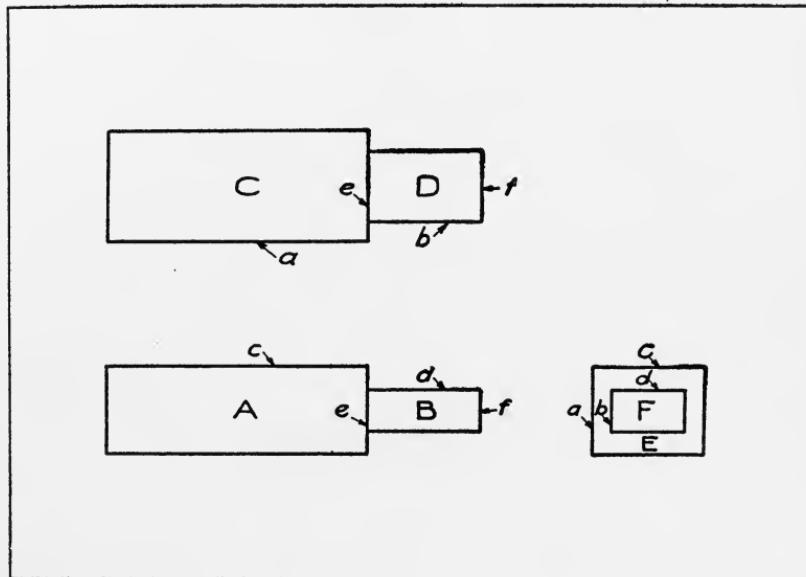


FIG. 6.

mark the surfaces. The corresponding small letters mark the lines which in other views represent these same surfaces. These letters are shown merely by way of explanation and would not appear upon a working drawing. From this drawing it will be seen that whenever a surface lies flat and on a level with the eye, it is represented by a line.

3. Making the Drawing.—In making the drawing in Fig. 6, we would draw the side view *AB* first, laying off the various dimensions with the scale. Then in drawing the top view *CD* we would use the principle of projections to simplify the work and to locate the view properly with respect to the side view. The vertical (up and down) lines on the side view we would

extend or project upward with a triangle. These lines would then show the lengths of the horizontal (crosswise) lines of the top view. After deciding how much space to leave between the views, we would then draw the horizontal lines of this view, spacing them properly with the aid of the scale, to show the desired width of the object. The right-end view is drawn in a similar manner, by extending toward the right the horizontal lines of the side view and locating the vertical lines with the aid of the scale. These lines, which are drawn from the side view in determining the other two views, are called *projection lines*. They are usually drawn lightly so that they may be readily erased from the finished drawing. The distance to be left between the views is largely a matter of choice. The considerations which govern it will be developed later. From the preceding discussion it will be seen that the following relations exist between the different views:

The horizontal dimensions of the side view and of the top view are equal.

The vertical dimensions of the side and end views are equal.

The horizontal dimensions of the end view and the vertical dimensions of the top view are equal.

4. Dimensioning the Drawing.—After the representation of the object is completed, it must be dimensioned for the guidance of the mechanics who are to have a part in its manufacture. Fig. 7 shows a shop drawing of the tenon shown in Fig. 5. It will be noticed that the extension lines and dimension lines have been added.

Dimension lines are light lines broken at the center for the insertion of the dimensions, and having arrowheads at their ends to show the distances which they measure. The arrowheads should be made very sharp. As shown in Fig. 8, they should have a sharp wedge shape with a slight curve to the sides rather than a straight V-shape. They should not be blocked in solidly.

Extension lines are light lines which show the points on the object between which the dimension is measured. Extension lines should be drawn up to about $\frac{1}{16}$ in. from the object and should project about $\frac{1}{8}$ in. beyond the dimension lines.

Dimension lines should be placed equally apart and equally distant from the object lines. About $\frac{5}{16}$ in. is a good average for this spacing. Dimensions should be placed in one or two views when possible. Notice in Fig. 7 that all the dimensions are

shown in two views. *It is bad practice to repeat dimensions—that is, to put the same dimension in more than one of the views.* Dimensions which are closely related should be placed near to each other, as shown by the arrangement of dimensions in the right-

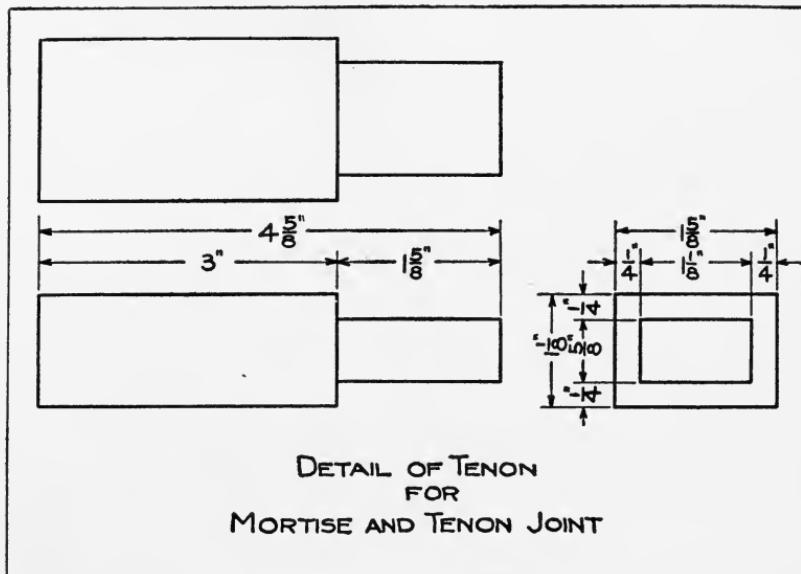


FIG. 7.

end view of Fig. 7. The dimension $4\frac{5}{8}$ in. is known as the *overall dimension*. It is usually given so that the workman may know the total length of material required. The overall dimension should be placed just outside the dimensions of which it is

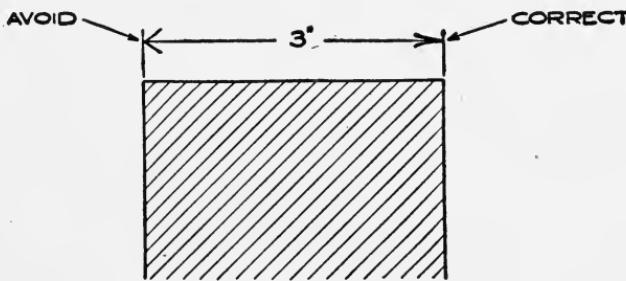


FIG. 8.

the sum, so that its dimension line will not be cut by any extension lines. Be sure that the sum of the small dimensions is the same as the overall dimension.

Dimensions are usually shown by vertical figures about $\frac{1}{8}$ in. high. Fig. 9 shows the type of numerals generally used. The total height of fractions should equal twice the height of the whole numbers. The dividing line of a fraction should be opposite the middle of the whole number and should be on a level with the dimension line. The figures of the fraction should not touch the dividing line. *All horizontal dimensions should read*

FREEHAND LETTERING

ABCDEFGHIJKLMNPQRSTUVWXYZ &

A B C S U 1234567890

ABCDEFGHIJKLMNPQRSTUVWXYZ &

1234567890 4 $\frac{5}{8}$ 3 $\frac{9}{16}$ 7 $\frac{1}{2}$

FIG. 9.

from the bottom of the sheet, and all vertical dimensions from the right-hand side of the sheet. Notice Figs. 7 and 11, in this respect. In all of the dimension lines that run up and down the sheet the dimensions are placed so that they can be read from the right-hand end of the sheet.

In Fig. 10 is shown a picture of an angle brace. A mechanical drawing of the angle is shown in Fig. 11. This drawing should be studied carefully, observing the following points:

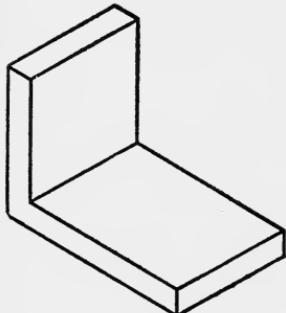


FIG. 10.

Relative positions of the views.

Relations between lines in the different views.

Arrangement and position of dimensions.

Extension lines and arrowheads.

5. Standard Sizes of Drawings.—

In making the drawing, the first thing to do is to determine the proper size of paper to use. In most drafting offices a regular system of standard sizes of sheets is used. For example, one office will take the standard letter size, $8\frac{1}{2}$ in. \times 11 in. for the smallest size, and base all other sizes on

this one, as 11 in. \times 17 in., 17 in. \times 22 in., and 22 in. \times 34 in. Another office will use 9 in. \times 12 in. for the smallest size, the others being 12 in. \times 18 in., 18 in. \times 24 in., and 24 in. \times 36 in. In this course of study two sizes will be used, 9 in. \times 12 in. and 12 in. \times 18 in.

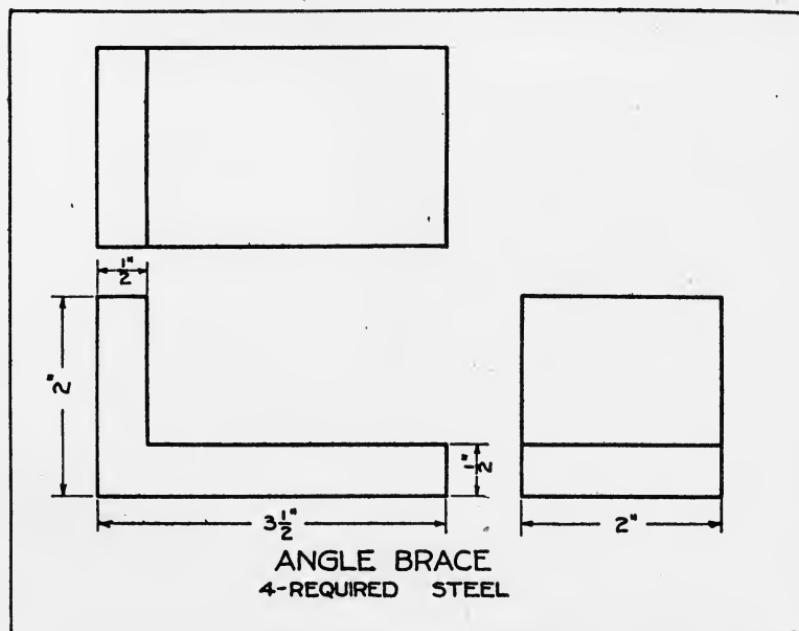


FIG. 11.

6. Drawing Board and T-square.—First take the drawing board, Fig. 12, and the T-square, Fig. 13, and place as in Fig. 14. This is the working position of the T-square, and the blade can be moved up and down over the surface of the board with the left hand while holding the head firmly against the working

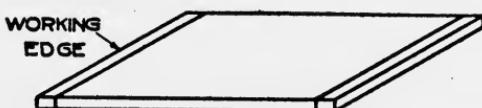


FIG. 12.

edge of the drawing board. For a left-handed man, the working edge of the board would be at the right, and the head of the T-square would be held in place with the right hand.

Drawing boards are made of soft wood, should be free from

knots and cracks, and should be provided with cleats across the back or ends.

The T-square consists of a head and blade, fastened together at right angles. The upper or working edge of the blade must be straight, and is used for drawing all horizontal lines (lines running the long way of the board).

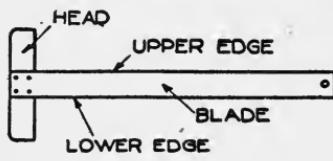


FIG. 13.

The left end of the drawing board must also be straight. The student can determine for himself whether, or not, the working edges of the T-square and of the drawing board are straight by holding them as shown in Fig. 15. They should be in contact along their entire length.

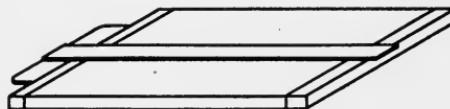


FIG. 14.

All horizontal lines should be drawn with the T-square, drawing from left to right, meanwhile holding the head of the T-square firmly against the working edge of the board with the left hand.

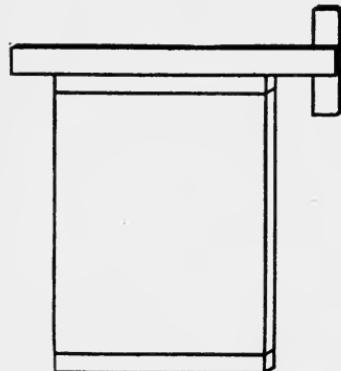
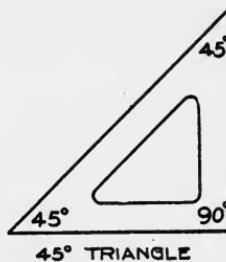


FIG. 15.



45° TRIANGLE



30° × 60° TRIANGLE

FIG. 16.

FIG. 17.

7. Triangles.—Triangles are used for drawing lines other than horizontal. They are made of hard rubber, celluloid, wood, or steel. There are two common shapes, called the 45° triangle and the 30° × 60° triangle. These are shown in Figs. 16 and 17. The 45° triangle, shown in Fig. 16, has one angle a right

angle, or 90° . The other angles are each 45° , just half of a right angle. The $30^\circ \times 60^\circ$ triangle shown in Fig. 17 has one angle a right angle; another angle is 60° (two-thirds of a right angle); and the other is 30° (one-third of a right angle).

For drawing vertical lines (lines at right angles to the horizontal lines), the T-square should be placed in its working position and one of the triangles placed against its working edge.

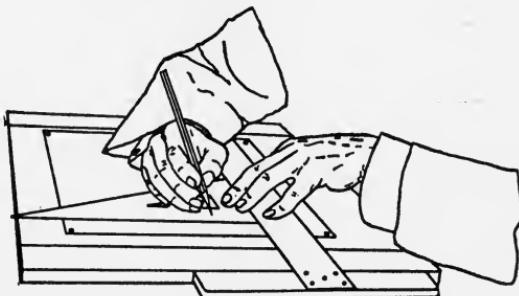


FIG. 18.

Fig. 18 shows the correct position of the hands and the method of holding the pencil for drawing these lines.

Always keep the working edge of the triangle toward the head of the T-square and draw from the bottom up, or away from the body.

8. Pencil.—The pencil must be properly sharpened and must be kept sharp. Good clean-cut lines cannot be made with a dull pencil. Sharpen your pencil as shown in Fig. 19. The

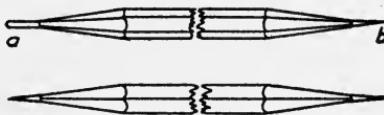


FIG. 19.

end *a* shows the chisel point used for drawing lines, while *b* shows the round point used for marking off distances and for putting in dimensions, lettering, etc. About $\frac{3}{8}$ in. of lead should be exposed in making the end *a*, and then it should be sharpened flat on two sides by rubbing on a file or piece of sandpaper.

9. Scale.—If you have the triangular scale called for in the list of materials, you will find on it eleven different scales, two on each edge, except where the full-size scale is shown. For the

present we will use only the full-size scale shown on the top edge of Fig. 20. This is the same as the scale of an ordinary foot rule divided into 16 parts to the inch. The uses of the other scales will be explained when we come to use them.

10. Starting the Drawing.—The size of the sheet required for the drawing in this assignment is 9 in. \times 12 in. As this is one-half the size of sheets specified in the list of materials, it is neces-



FIG. 20.

sary to cut one of the sheets into two equal parts. Use the back of the board and the lower edge of the T-square as a straight edge. Cut with a sharp knife. See Fig. 21. Then place a 9-in. \times 12-in. sheet of drawing paper near the center of the working surface of the board, with the 12-in. dimension running the long way of the board. Fasten the sheet to the board by placing a thumb tack in the *upper left-hand* corner of the sheet. Swing the

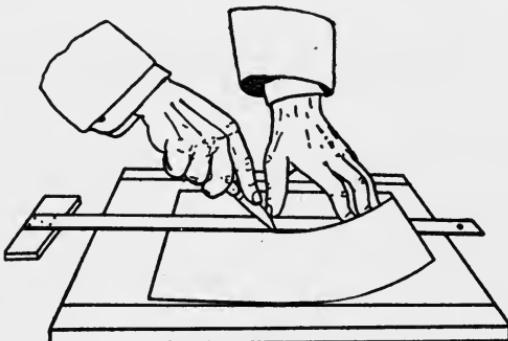


FIG. 21.

sheet, if necessary, to bring its upper edge in line with the working edge of the T-square when held in position. When the top of the paper is parallel with the blade of the T-square, put a thumb tack in the *lower right-hand* corner of the sheet. Then put tacks in the other two corners, after stroking the paper gently toward the corner in which the tack is to be placed.

Now, starting $\frac{1}{2}$ in. from the top and 1 in. from the left end, draw horizontal and vertical lines to form a rectangle 8 in. \times 10 $\frac{1}{2}$

in. in size. The sheet should now appear on the drawing board as shown in Fig. 22, except that there will be no dimensions or lettering on it. This leaves a margin of $\frac{1}{2}$ in. on three sides and 1 in. on the left end. This wider margin on the one end is for

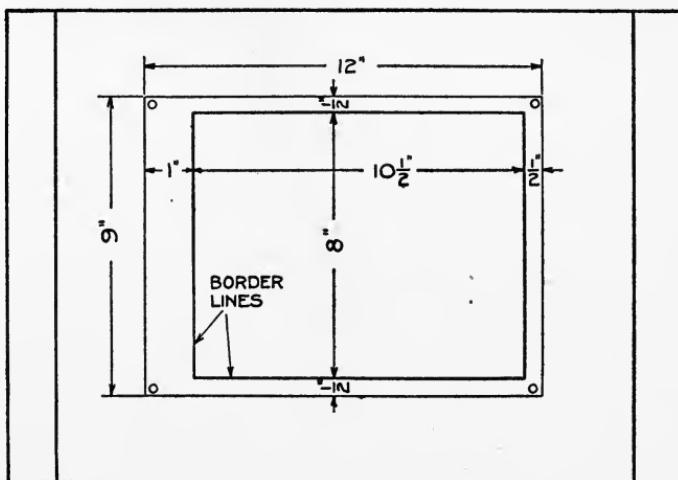


FIG. 22.

the purpose of binding together several drawings, where that is desired for any reason.

Problem 1

Fig. 23 shows a sketch of a gib key. A working drawing of this key is shown in Fig. 24 with an appropriate title. Such a key is used for fastening

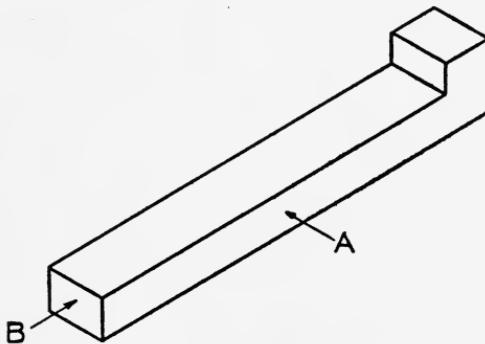


FIG. 23.

pulleys, couplings, or collars to shafts and is driven into a slot, half of which is cut in the shaft and half in the piece to be fastened to the shaft. The

head is used for pulling the key out of the slot. The slots cut in the shaft and pulleys are called "keyways." Fig. 25 shows the same key as in Figs. 23 and 24, but viewed from a different position.

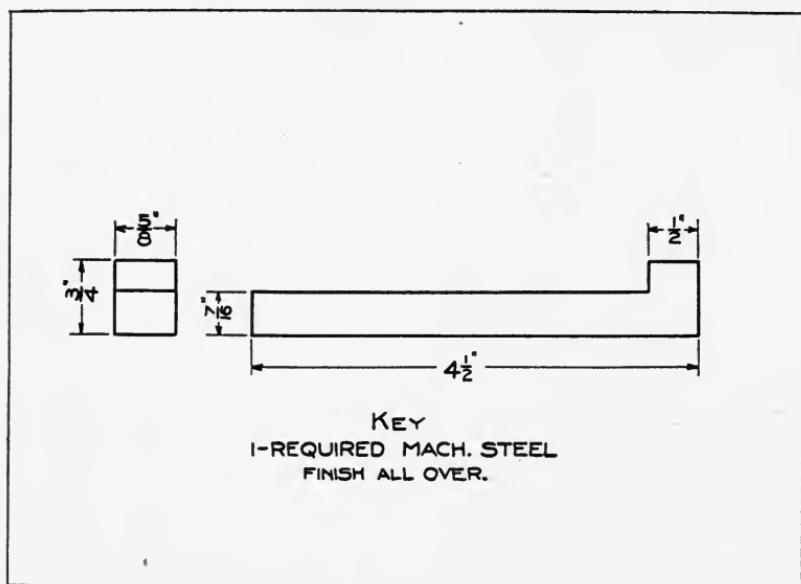


FIG. 24.

Make a pencil drawing of this gib key, making the views the full size of the key according to the dimensions given in Fig. 24. *Draw the views of the*

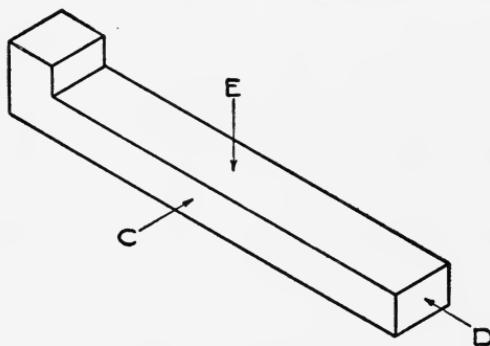


FIG. 25.

key that would be obtained by looking along the arrows C, D, and E, in Fig. 25. The arrangement of views should be as shown in Fig. 26.

The first thing to do is to determine the proper location of the views on the sheet. They should be placed so that the whole drawing will be cen-

tered on the sheet. Since the key is to be $4\frac{1}{2}$ in. long, this will be the length of the side view and of the top view. The end view will be $\frac{5}{8}$ in. wide and, if we allow $\frac{3}{8}$ in. between views, the drawing will take up $4\frac{1}{2}$ in. + $\frac{3}{8}$ in. + $\frac{5}{8}$ in. = $5\frac{7}{8}$ in. We will divide the remaining space so as to leave an equal amount on each end between the views and the border lines. The length between the border lines is $10\frac{1}{2}$ in. and the views occupy $5\frac{7}{8}$ in.

$$10\frac{1}{2} \text{ in.} - 5\frac{7}{8} \text{ in.} = 4\frac{5}{8} \text{ in.}$$

$$4\frac{5}{8} \text{ in.} \div 2 = \frac{37}{8} \text{ in.} \times \frac{1}{2} = \underline{\frac{37}{16}} \text{ in.} = 2\frac{5}{16} \text{ in.}$$

Therefore, we have $2\frac{5}{16}$ in. at each end between the views and the border line.

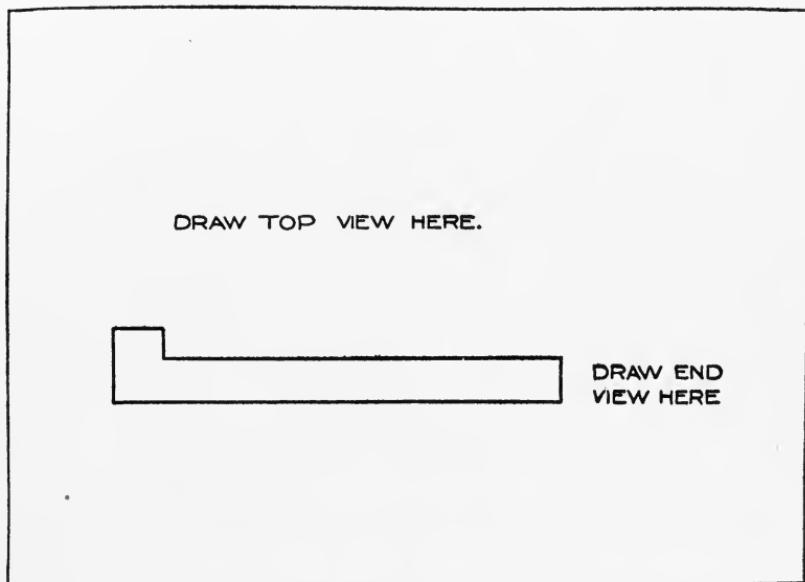


FIG. 26.

Vertically, the views occupy $\frac{3}{4}$ in. for the side view, $\frac{3}{4}$ in. between views, and $\frac{5}{8}$ in. for the top view, so that $\frac{3}{4}$ in. + $\frac{3}{4}$ in. + $\frac{5}{8}$ in. = $2\frac{1}{8}$ in. The working space on the sheet is 8 in. high.

$$8 \text{ in.} - 2\frac{1}{8} \text{ in.} = 5\frac{7}{8} \text{ in.}$$

$$5\frac{7}{8} \text{ in.} \div 2 = \frac{37}{8} \text{ in.} \times \frac{1}{2} = \underline{\frac{37}{16}} \text{ in.} = 2\frac{5}{16} \text{ in.}$$

Thus we have a space of $2\frac{5}{16}$ in. both above and below the views. By referring to Fig. 27, we see that the corner *A* is thus located $2\frac{1}{8}$ in. above the lower border line, and $2\frac{5}{16}$ in. from the left border line.

Through the point *A* which we have just located, draw a fine horizontal line. On this line, lay off from *A* $4\frac{1}{2}$ in. to the right, thus locating the point *B*. Measure to the right from *B* $\frac{3}{8}$ in. and we have the point *C*; then measure $\frac{5}{8}$ in. to the right of *C* and we get point *D*. Through the points

A, B, C, and D draw light vertical lines, using the T-square and triangle as shown in Fig. 18.

On the vertical line through *A* lay off $AE = \frac{3}{4}$ in. On the vertical line through *B* lay off $BG = \frac{7}{16}$ in. Then measure up from *E* $\frac{3}{4}$ in. for the space between the views, and $\frac{5}{8}$ in. more for the width of the top view. Draw a horizontal line through *E* to the right until it crosses the vertical lines drawn through *C* and *D*. This gives the height of the side view and the end view. Now measure $\frac{1}{2}$ in. from *E* to the right, locating the point *F*. Draw a vertical line downward from *F* and then a horizontal line to the left from *G* until it intersects the vertical line. The outline of the side view is thus completed. The top and end views are not complete, however, and the student should determine for himself what lines are necessary to complete these views and should put them in. Now go over all the object

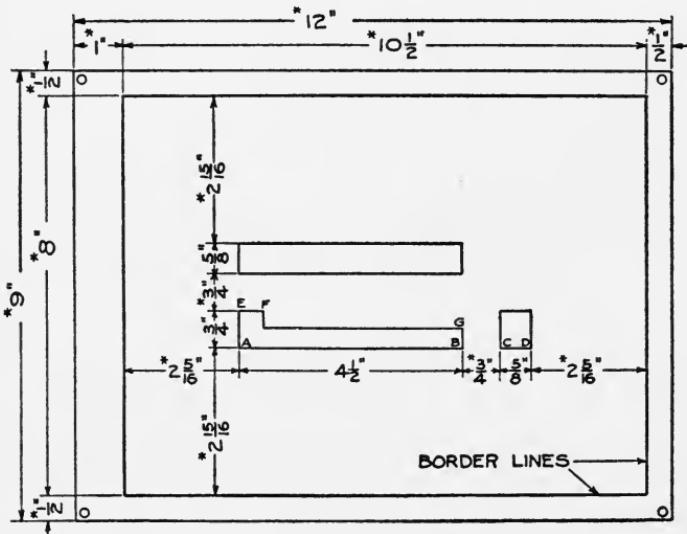


FIG. 27.

ines and make them heavier, and with the pencil eraser, erase all other lines that have been used in constructing the views.

The extension lines should be drawn next. These are light, solid lines drawn from the ends of the views and between which the dimensions are placed. The extension lines should not touch the views by about $\frac{1}{16}$ in. and should be about $\frac{1}{2}$ in. long.

Now put in the dimension lines, drawing them about $\frac{3}{8}$ in. from the views. The extension lines and dimension lines should be placed on the drawing about as shown in Fig. 24, and should not be as heavy as the outlines of the views. Leave a break near the center of the dimension line for the dimension or figures. Now put arrowheads at the ends of the dimension lines. They should be drawn as shown in Fig. 8.

Use vertical figures for dimensions, making them about $\frac{1}{8}$ in. high. Make each figure of a fraction as large as the whole number, and be careful

that they do not touch the dividing line. The dividing line of a fraction should be on a level with the dimension line.

Horizontal dimensions should read from the bottom of the sheet, and vertical dimensions from the right-hand side of the sheet. See Fig. 24. All dimensions that do not give the size of the object should be omitted from the drawing, as, for example, those marked (*) in Fig. 27. These are given only to show how the views are located on the sheet.

Fig. 28 shows the arrangement of the title for this drawing. This arrangement is used throughout the course, the number of the lines varying with the different problems. More can be added, or some omitted. The name of the object shown on the plate is the most important part of the title, and therefore is put in the first line and in the largest letters. If the name of the machine for which the part is used is given, it should be placed in the next line, but in smaller lettering. The number of parts required, the material, the scale of the drawing, and the date will vary with the different plates, but should be arranged as shown. The number of the plate should go in the corner, as indicated in Fig. 28.

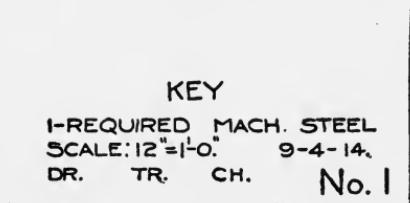


FIG. 28.

The items *DR.*, *TR.*, and *CH.*, in the title are to be followed by the initials of the persons who have *drawn*, *traced* and *checked* the drawing. It is quite common in drafting offices to require that this information be given on every drawing so that responsibility can be placed for any errors that may be found.

The item in this title *Scale: 12" = 1'-0"* refers to the *scale* of the drawing, that is the relation between the size of the drawing and the size of the actual object which it represents. $12" = 1'-0"$ means that 12 in. on the drawing are used to represent 1 ft. of actual object. Therefore, this drawing is full size. When the scale of a drawing is $3" = 1'-0"$, then 3 in. on the drawing represents an actual length of 1 ft., or the drawing is only one-fourth the actual size of the object.

A good, simple type of lettering to use is shown in Fig. 9, which also shows the general method of making the letters. The strokes of the pen should all be made either downward or to the right, thus minimizing the danger of blotting. Fig. 9 also shows the best forms for the numbers. Considerable practice is necessary to do a good job of lettering, and the student should not be discouraged by the results of his first attempt.

ASSIGNMENT 2

11. Broken Lines.—In drawing any view, if a surface is hidden from sight but needs to be shown in some manner, it is customary

to use a broken line. This line will show the location and extent of the hidden surface, but, by being broken, will indicate that the surface represented is not on the front but is out of sight.

Broken lines are drawn with dashes about $\frac{1}{8}$ in. long with spaces about $\frac{3}{2}$ in. long between them. See Fig. 42. In

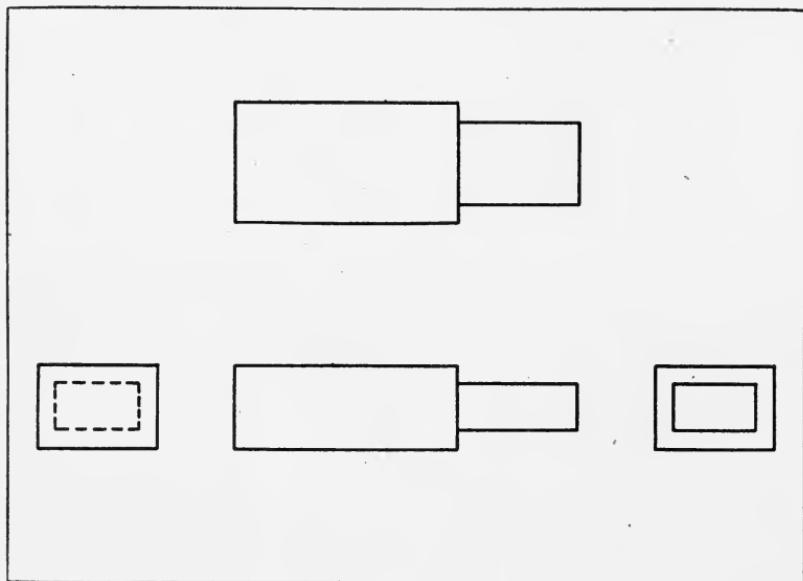


FIG. 29.

drawing broken lines, they are usually made just a little lighter than the full object lines of the drawing.

A judicious selection of the views to be shown will often avoid the necessity of using broken lines. For example, the right-end

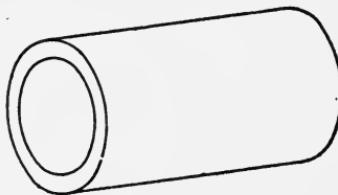


FIG. 30.

view of Fig. 29 shows the end outline of the tenon in full view and therefore is preferable to the left-end view. Figs. 30 and 31 show a case where the broken lines are needed. These figures show a picture and a mechanical drawing of a bronze bushing.

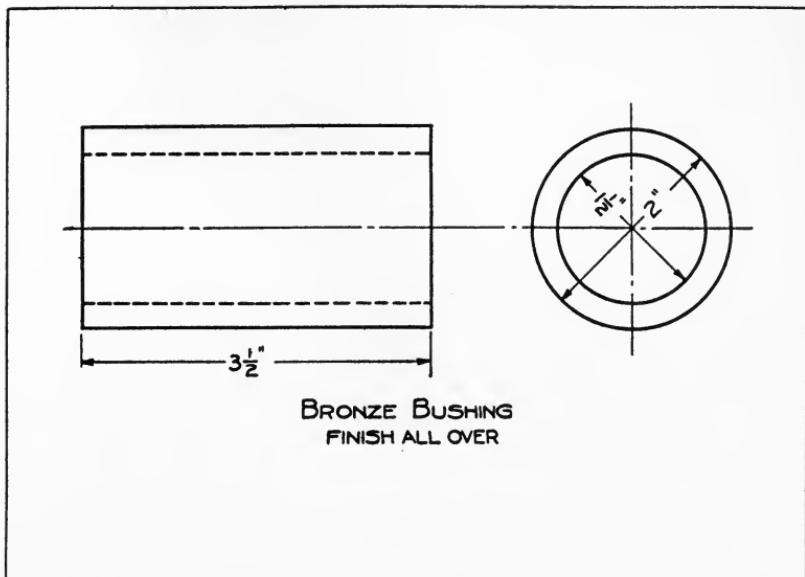


FIG. 31.

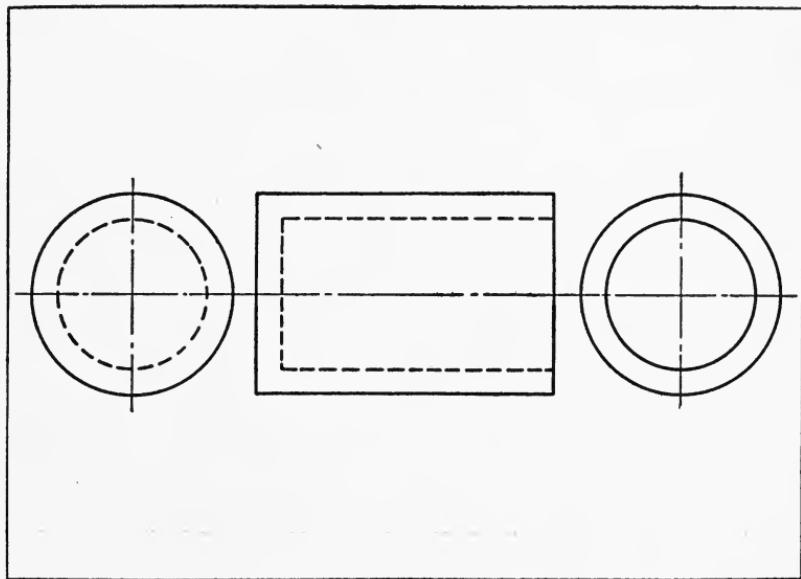


FIG. 32.

This is a hollow cylinder, the hole extending clear through from end to end. In the side view of Fig. 31 it is necessary to represent the hole by two broken lines.

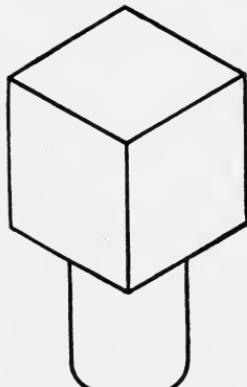


FIG. 33.

These lines extend throughout the length of the side view and thus indicate that the hole extends from one end of the piece to the other. Without these lines we could not tell how far the hole extended. These lines are located by projecting the top points of the inner circle of the end view.

Suppose now that we were to make a cylinder like that of Fig. 31 but closed at one end so that it would look like a cap for a pipe. It might then be shown by the side view and right-end view of Fig. 32. Notice how the broken outline in the

side view shows the form of the interior and indicates that the hole does not extend all the way through the piece. These two

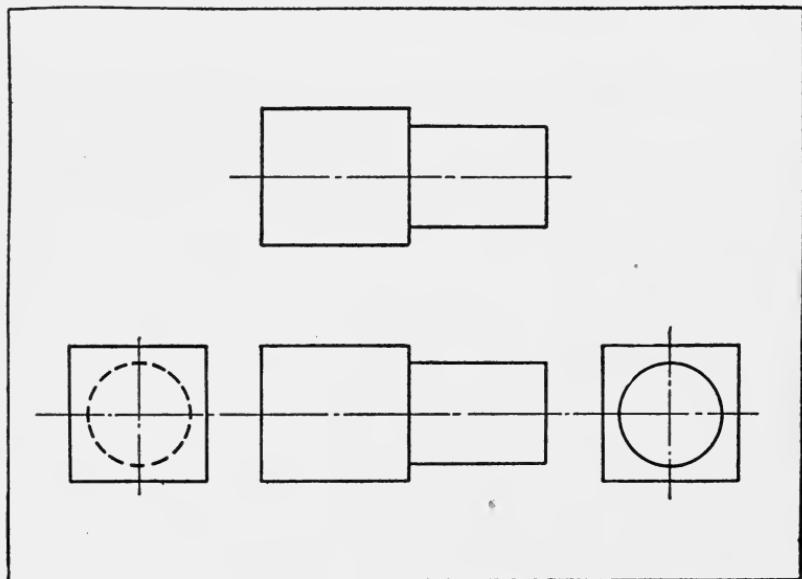


FIG. 34.

views would be sufficient to give a clear idea of the cap. If the left-end view were desired, it would appear as shown at the left.

The inner circle of this view is broken because it represents a hidden surface.

Fig. 33 shows a "stop" such as is commonly used on planer beds for bracing castings. It is shown by four views in Fig. 34. These views are not all needed, but are given to show how the stop would appear in the different views. The left-end view contains a broken circle, because the surface which it represents is concealed when the stop is viewed from the left-end. The side view and right-end view are all the views needed to give a complete idea of the shape of this stop.

Fig. 35 shows a sketch of a flange bushing. A complete shop drawing of this flange bushing is shown in Fig. 36. When the

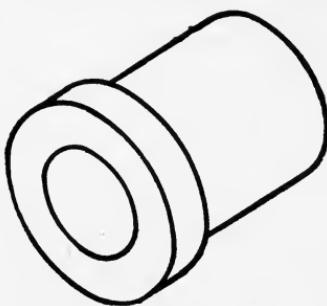


FIG. 35.

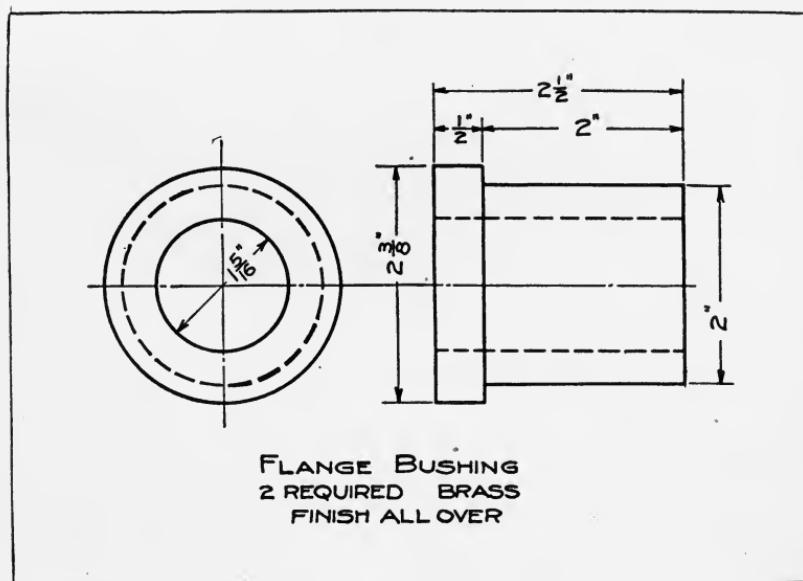


FIG. 36.

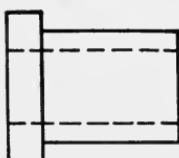
bushing is viewed from the left end, the 2-in. cylindrical surface is concealed from sight by the flange, and is therefore shown by a broken line in the left-end view.

Always end a broken line with a dash running right up to the point where the surface ends which the line represents. Compare the ends of the lines in Figs. 37 and 38. Whenever a broken line crosses a full line, always make one of the dashes definitely cross the full line. The correct method of observing this is also shown in Fig. 37, and the improper method is shown in Fig. 38.

If the bushing is shown on a shaft, the diameter of which is the same as that of the hole, then the broken lines will terminate as shown in Fig. 39. This explanation applies not only to this particular problem, but to all similar cases.

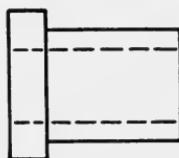
In all work in drawing, full-line views should be shown, whenever possible, rather than broken-line views. For instance, in drawing the cap of Fig. 32, it is better practice to show the side view and right-end view rather than the side view and left-end

CORRECT AND INCORRECT METHODS OF SHOWING BROKEN LINES.



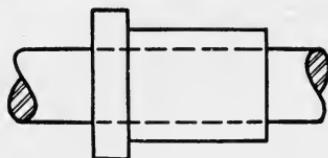
CORRECT

FIG. 37.



AVOID

FIG. 38.



CORRECT

FIG. 39.

view, because in the former case all of the lines of the end view are full lines, while in the latter case one of the circles is broken.

12. The Compass.—The compass is an instrument used for describing circles. It is provided with a needle point on one leg, and a pencil or pen point on the other leg, as shown in Fig. 40. A lengthening bar is also provided for making large circles. In order that all lines on the drawing may be of the same weight the student should take some lead from his drawing pencil and insert it in the pencil section. Fig. 41 shows how the compass is used. Note that both the needle and pencil sections are vertical to the plane of the paper. This is the proper way to hold the compasses, because if the points are not vertical to the paper, a slight pressure will cause them to spread apart, thus spoiling the circle or curve. Do not bear upon the needle point or it will dig large holes in the paper. A slight pressure will be necessary on the pencil point. The lead should be sharpened from the outside only, using a knife, or better a smooth file, emery cloth,

or sandpaper. Do not touch the inside. The point will then produce sharp lines and stand considerable usage without resharpening.

13. Center Lines.—It will be seen that light dot-and-dash lines are shown through the center of views of Figs. 31, 32, 34 and 36. These are known as *center lines*. Whenever an object is symmetrical about a common center line (that is, just alike on both sides of the center line) it is customary to show the center line on the drawing. The most common method is to use a line made up of dashes about an inch long with single dots between. Center lines should be drawn lightly. Both the horizontal and vertical center lines of all circular views should be shown. *In starting a drawing, the center lines should always be the first lines drawn.*

In making a drawing like Fig. 31, the center lines would be drawn first, and the circular end view next. The side view may then be constructed with the aid of projection lines from the end view. The object lines of a drawing, whether full or broken,

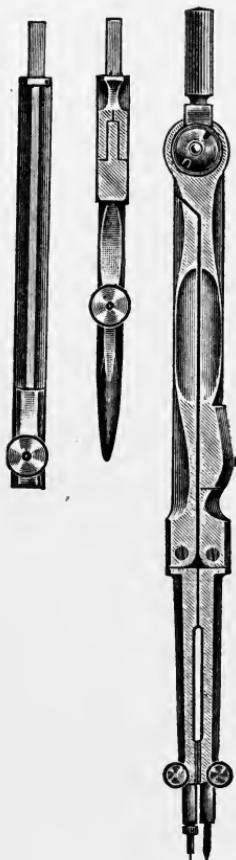


FIG. 40.

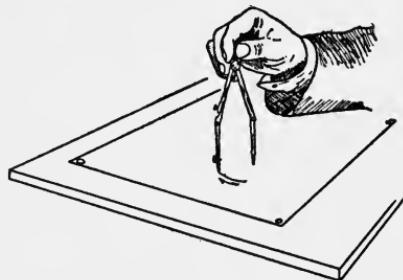


FIG. 41.

should be heavier than the center, extension, and dimension lines, as shown in Fig. 42. To obtain this result, the pencil should be sharpened carefully at the beginning of the work. This will enable the student to draw fine but distinct center lines. The object should then be drawn, making the lines heavier. After completing the views, the pencil should be sharpened again

preparatory to drawing the extension and dimension lines, which should also be fine lines.

FULL LINES

BROKEN LINES

EXTENSION LINES



CENTER LINES

FIG. 42.

14. Arrangement of Dimensions.—Always dimension full-line views rather than broken-line views. Dimensions should be placed as close as possible to the place which they measure so

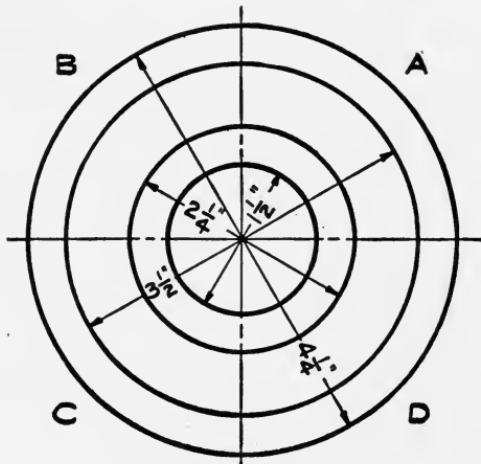


FIG. 43.

as to avoid the use of unnecessarily long extension lines; for example, in Fig. 36 notice how the extension lines for the $2\frac{3}{8}$ -in. dimension are drawn to the side view rather than to the end view.

Dimensions should always be carried outside of the views of the drawing when convenient, so that the drawing may be the more easily read.

In Fig. 36, it will be noticed that the hole is dimensioned on the end view, in which it appears as a circle. This is done because to dimension it on the other view would necessitate dimensioning from hidden lines, which is undesirable. Dimensions placed in this way should be put on a slant so as to avoid the center lines. A single dimension should slope 45°; that is, half-way between the horizontal and vertical center lines. Fig. 43 shows how a number of dimensions would be arranged on a circular end view, the dimension lines being arranged so as to divide evenly the spaces between the center lines.

15. Finish.—In several of the drawings shown, there appear in the title the words, "Finish All Over." This indicates that all the surfaces are to be machined to the dimensions shown in the drawing. The piece must therefore come to the machinist with extra stock all over and on the inside so that he can machine it to size. If a piece is cast, the pattern-maker must allow for this in making the pattern; if forged, the blacksmith must leave the extra material in forging. Different shops may use different phrases, such as *Finish*, *Finished*, *Finish All Over*, *Fin.*, or the letters *F. A. O.*.

Problem 2

Make a full-size pencil drawing of the flange bushing shown in Figs. 35 and 36, drawing the *side elevation* and *right-end view*. Use a 9-in. \times 12-in. sheet. Careful attention must be given to all directions contained in articles 11 to 15 inclusive.

ASSIGNMENT 3

16. Finish Marks.—Fig. 44 shows a full-size drawing of a rocker arm. This drawing illustrates several features that have not been explained before.

This rocker arm is not to be finished all over, but only on the faces and through the holes of the head and of the hub. When a flat surface, such as the faces of these ends, is to be finished, the general practice is to put a letter *f* across the line representing this surface. Some concerns use the capital *F*, others the abbreviation *Fin.*, while still others put the whole word *FINISH* in capitals just outside of the line. The finish mark *f* shown in Fig. 44 will be used in this course because it is in most general

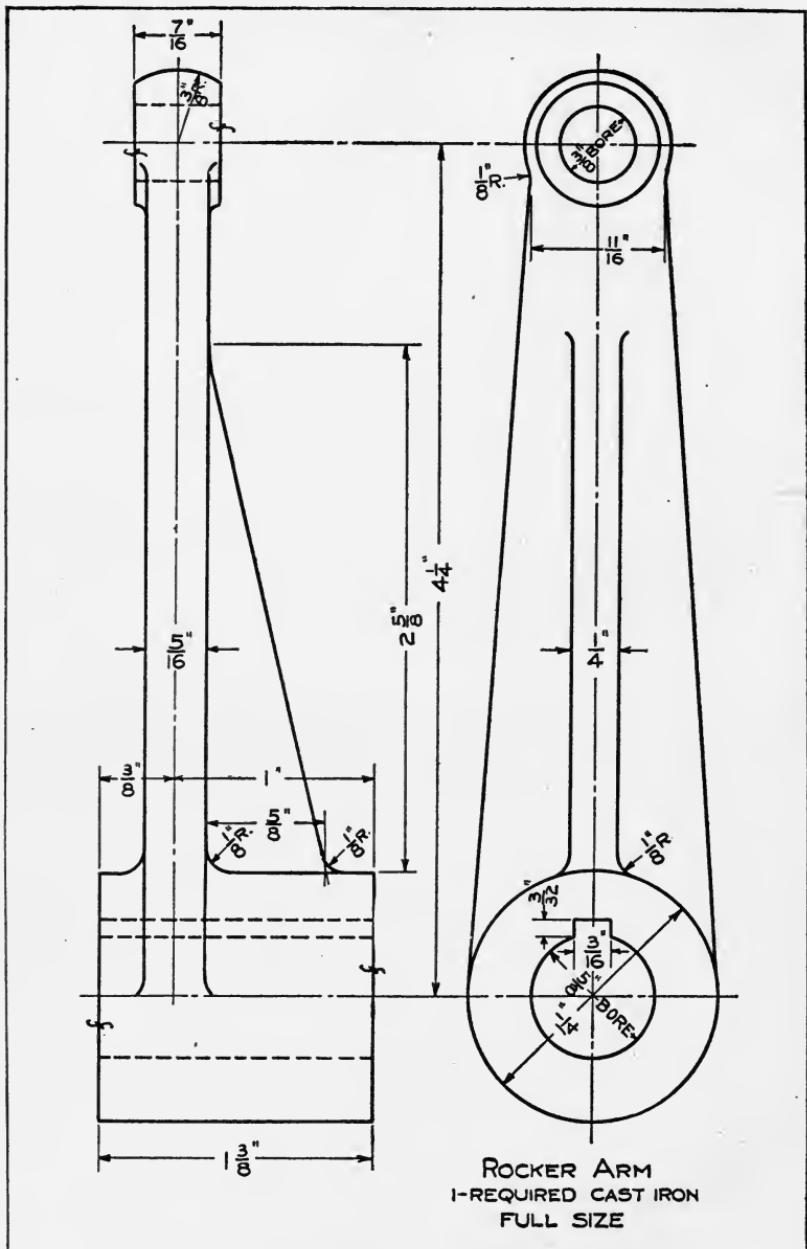


FIG. 44.

usage. If a student is employed in a shop having different standards, it is suggested that he learn them and use them throughout his work. Notice particularly that, when a surface is to be finished, the finish marks are not placed on the view where the surface is shown in plan, but rather on the view where it is represented by a line. Wherever these marks appear, the pattern-maker or blacksmith allows extra stock. About $\frac{1}{16}$ in. is allowed on small parts, so that, if the draftsman leaves off a finish mark where there should be one, it is the same as making an error of $\frac{1}{16}$ in. The finish marks indicate to the machinist what work is to be done by him on the object.

When a hole in an object is to be machined, it is customary to indicate the process to be used by printing the word after the dimension of the hole. Thus in Fig. 44 we have $\frac{3}{8}$ -in. *BORE* and $\frac{5}{8}$ -in. *BORE* to indicate that the holes in the ends of the rocker arm are to be bored out to the given dimensions. In Fig. 45 is shown a hexagonal (six-sided) hole in a wrench. The word *BROACH* indicates that the hole is to be finished by the broaching process. The forging for the wrench must therefore be made so that this hole will be undersize, leaving material to be removed by the broach. Likewise, we find holes marked *REAM*, *DRILL*, or *TAP*, according to the operation to be used in finishing the hole. In a similar manner cylindrical parts that are to be finished by turning in a lathe have the word *TURN* after the dimension.

17. Fillets.—In the views of Fig. 44 it will be noticed that the faces of the arm are rounded into the hub instead of leaving a sharp corner. A further examination of the figure shows that this is done wherever two surfaces meet, so that there will not be any sharp corners on the object when made, except where it is to be finished. These small curves or arcs on the drawing represent fillets. A *Fillet* is a small curve used to avoid sharp corners where two surfaces come together at abrupt angles. *All unfinished corners should be rounded by fillets*, so as to provide for the smooth flow of the metal when casting or forging and also for strength, as a crack will generally start in a sharp corner if the piece is overstrained.

These fillets are dimensioned by giving the radius, as is done with any curve which is not a complete circle.

18. Notes on Dimensioning.—There are several new features in connection with the dimensioning of this drawing in Fig. 44.

A fillet is dimensioned by a line drawn from the curve to the center from which the arc was swung. The arrowhead appears only on the one end next to the curve. The note $\frac{1}{8}$ -in. R is put at the other end and in line with the arrow. If the dimension line had been long enough it might have been broken and the dimension put in the break, as was done in the $\frac{3}{8}$ -in. R on the head of the rocker arm. Notice that the distance between the center lines of the hub and head is given, rather than the overall dimension. This is the important dimension and must be made accurate in machining. In the side view at the left, the faces of the head and hub must be located accurately with respect to each other. It would not do to locate these from the unfinished face of the arm, so they are located from the center line of the arm. The width of the head is given as $\frac{7}{16}$ -in. overall, but, since it is symmetrical about the center line, it is understood that this means $\frac{7}{32}$ in. on each side of the center line.

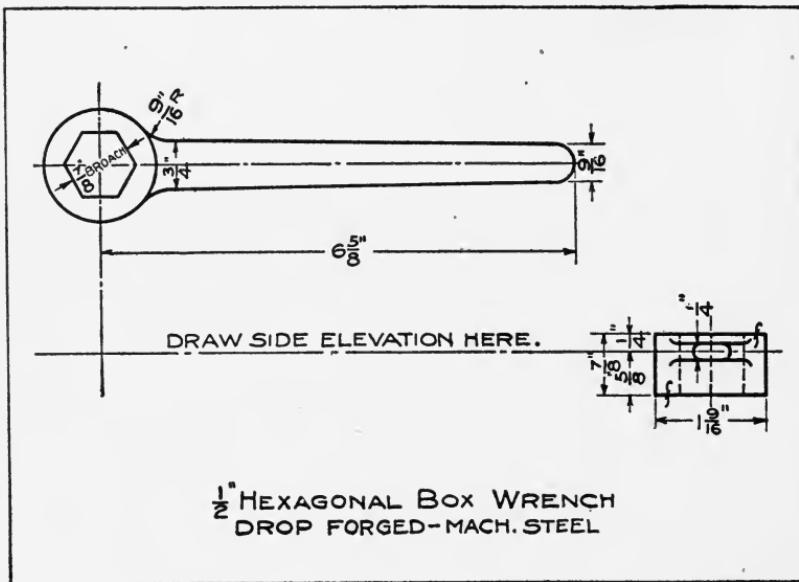


FIG. 45.

This drawing shows several cases where the space between the extension lines is very limited. This is especially true of the keyway cut through the hub. In giving the width of the keyway there was space enough for the figures but not for the arrows, so we put the arrows outside, pointing inward. The depth of the

keyway is still narrower. Here the arrows both point in, and the dimension is placed outside and in line with one of the arrows.

Problem 3

Make a full-size pencil drawing of the $\frac{1}{2}$ -in. hexagonal box wrench, shown in Fig. 45. Use a 9-in. \times 12-in. sheet. In this sketch, only the top and right-end views are shown. The student is to show the top, right-end, and side views. Draw the top and right-end views first, and from them draw the side view by means of the principles of projection.

Order of Work: Always start by laying out the center lines. Locate them so that there will be sufficient room between views and so that the three finished views will balance up well on the paper. It is always best to draw the circles and the curved surfaces first and then connect them with straight lines, as smoother joints will result. However, it is not practicable to do this in all cases. In this problem, start with the head of the wrench.

The head of the wrench is formed to fit a hexagonal nut for a $\frac{1}{2}$ -in. bolt and is therefore known as a $\frac{1}{2}$ -in. wrench. The size of wrench is always designated by the size of the bolt whose nut or head it will span, rather than by the size of opening of its jaws.



FIG. 46.

The hexagon is a regular six-sided figure. Fig. 46 shows the method of constructing the hexagon. Draw the two center lines, and with the point where they cross as a center and a radius of $\frac{7}{16}$ in., draw a circle (a $\frac{1}{2}$ -in. nut has a short diameter of $\frac{1}{4}$ in.). Tangent to this circle, draw the horizontal lines 1-2 and 5-4. Draw the lines 2-3, 3-4, 5-6, and 6-1 tangent to this circle and making angles of 60° with the horizontal. This completes the hexagon.

ASSIGNMENT 4

Problem 4

Two views of a stuffing box gland are shown in Fig. 47. As these views are not the best combination for giving a clear idea of the object, the student should draw in pencil the views shown in outline in Fig. 48, using the full-size scale. Use a 9-in. \times 12-in. sheet, with the 12-in. dimension vertical on the board.

Draw the center lines first, locating them in such a way that the views will be centered on the sheet, at the same time providing sufficient room in the lower right-hand corner for the title. Allow about $\frac{3}{4}$ in. between the views. Draw the $\frac{5}{8}$ -in., $1\frac{1}{4}$ -in., and $2\frac{3}{16}$ -in. diameter circles first. Then draw the $\frac{5}{8}$ -in. radius arcs at the ends, from the centers *B* and *C*, as shown in Fig. 49. The distance across the middle of the gland is $2\frac{3}{4}$ in. Take one-half of this, or $1\frac{1}{2}$ in., for a radius and with a center at *A* draw arcs above and below the horizontal center line. As yet you have not determined the lengths of the arcs, but make them longer than necessary and then the excess length can be erased later.

Now draw straight lines *DE* and *FG* tangent to the arcs of $\frac{5}{8}$ -in. and $1\frac{1}{8}$ -in. radii. Take your triangles and place them on the drawing with the upper edge of the 45° triangle coinciding with line *FG* that you have just drawn. Then holding the $30^\circ \times 60^\circ$ triangle securely, slide the 45° triangle along it to the right until its left-hand side passes through the point *A*. Draw a fine pencil line *AF*. Still holding the 30° triangle securely, slide the

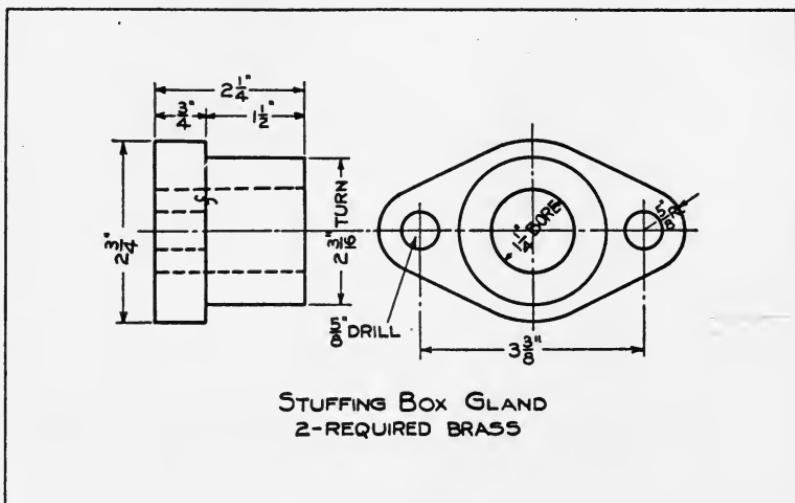


FIG. 47.

45° triangle further to the right until its left-hand edge passes through the point *C*. Draw a fine pencil line *CG*. The two lines *AF* and *CG* are parallel (the same distance apart along their whole length). This will give you the points where the arcs and the straight line *FG* meet. Find the other points where the arcs and straight lines meet in the same way. These fine pencil lines *BD*, *AE*, *AF*, *CG*, etc., should not be erased until after you have completed the drawing.

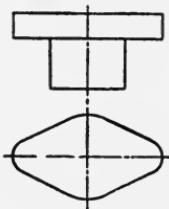


FIG. 48.

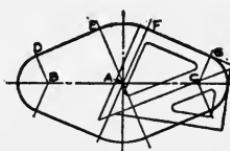
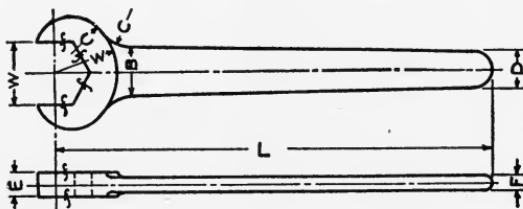


FIG. 49.

The stuffing box gland is used on steam engines, pumps, etc., for keeping the packing tight around the piston rod so that it will not leak. The diameter of the piston rod in this case would be $1\frac{1}{4}$ in. Examine a steam engine or steam pump and see if you can find a gland similar to this.

ASSIGNMENT 5

19. Use of Formulas.—It quite frequently happens in practice that the draftsman is required to use formulas in determining the dimensions of certain pieces. A knowledge of the use of formulas is, therefore, essential. When a line of several different sizes of a tool or machine part is being designed, the different dimensions are sometimes made proportional to some fundamental dimension of each size. For example, Fig. 50 shows an open-end hexagon wrench dimensioned in letters. By the use of suitable formulas the dimensions represented by these letters may be calculated for any size of wrench. The following formulas, taken from "Machinery" data sheets, will enable the student to calculate the dimensions for any size of wrench, or for



SINGLE END HEXAGON WRENCH

FIG. 50.

a whole series of sizes. The width of opening, or size of the nut, would be the first thing known, so that is taken as the basis for all of the other dimensions.

W = width of opening.

B = $0.8 \times W$.

D = $0.65 \times W$.

E = $0.4 \times W$.

F = $0.25 \times W$.

L = $7 \times W$.

C = distance from center of hexagon to one corner (to be measured on the drawing).

As an example of the use of these formulas, we will start the calculations for the problem of this assignment, which calls for the design of a $\frac{3}{4}$ -in. open-end hexagon wrench, the opening (W) of which would be $1\frac{1}{4}$ in.

We can, therefore, start with the fact that the dimension W of our wrench is to be made $1\frac{1}{4}$ in. The formula for B , the width of the handle next to the head, states that:

$$B = 0.8 \times W.$$

Since $W = 1\frac{1}{4}$ in., the above formula means that $B = 0.8 \times 1\frac{1}{4}$ in. This may be done either decimal or fractionally. The fractional method is better because it is more desirable to obtain the answer in fractions than in decimals. Changing 0.8 to fractional form we have $\frac{8}{10}$. Changing $1\frac{1}{4}$ in. to an improper fraction we have $\frac{5}{4}$ in.

Then $\frac{8}{10} \times \frac{5}{4}$ in. = $\frac{40}{40}$ = 1 in.

0.8 of W is, therefore, 1 in. Then our wrench of this size would have a handle 1 in. wide at the head. If the opening W of the wrench were larger, the handle would become correspondingly larger.

Likewise, we get the width at the end of the handle from the formula:

$$D = 0.65 \times W.$$

0.65 may be written $1\frac{65}{100}$.

Therefore, $D = \frac{65}{100} \times \frac{5}{4}$ in. = $\frac{325}{400}$ = $\frac{13}{16}$ in.

The other dimensions are calculated in the same way.

Problem 5

Using a 9-in. \times 12-in. sheet, make a pencil drawing for a $\frac{3}{4}$ -in. hexagon wrench of the type shown in Fig. 50, but making the views shown in Fig. 51. The width of opening W is $1\frac{1}{4}$ in.

From this dimension all of the other dimensions for the wrench should be calculated before trying to start the drawing. Two of the dimensions have already been calculated; the others should be calculated in a similar manner from the formulas given. The views are to

be made full size. In locating the wrench on the sheet, remember that the total length of the wrench is somewhat greater than L , being L plus one-half of one side of the hexagon.

Locate the drawing on the sheet so that there will be about $\frac{3}{8}$ in. between the views.

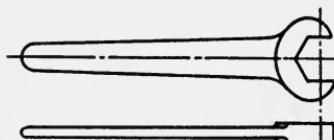


FIG. 51.

After locating the center of the hexagon, construct the hexagon for the wrench as explained for Fig. 46. In the drawing of the wrench two sides of the hexagon are omitted. To draw the head of the wrench: First, with the center of the hexagon as a center, draw an arc of radius W , then, with a radius C and a center which must be located by trial, draw an arc that will be tangent to the arc of radius W , and which also will pass through the outer corner of the hexagon, as the corner 1, of Fig. 46. Two of these arcs must be drawn, one above, and one below the center line of the wrench to complete the head.

The width B of the large end of the handle is drawn by laying off points one-half B above and one-half B below the center line of the wrench. Through the points thus found, draw horizontal lines and find the points where these lines intersect the curve of radius W . At the other end of the handle draw lightly a circle of diameter D . Through the points at the large

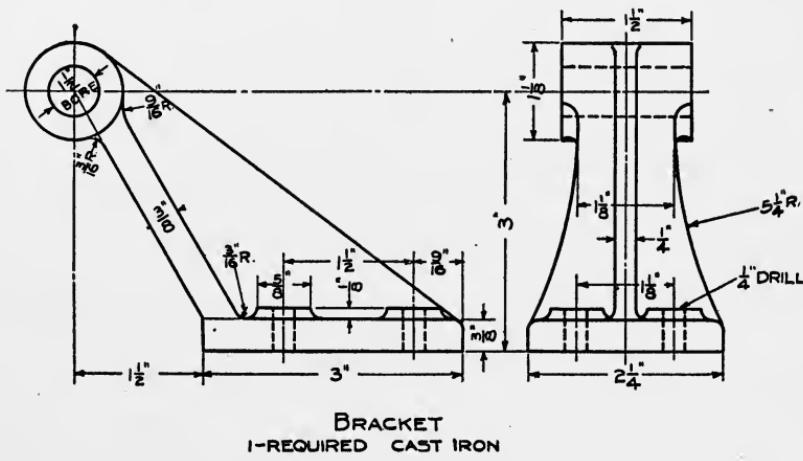


FIG. 52.

end and tangent to the circle at the small end of the handle, draw lines representing the sides of the handle. Instead of a sharp corner where the handle joins the head, arcs or fillets of radius C are used, which should now be drawn. In the other view the thickness of the head is E and that of the handle F . In this view the sides of the handle are parallel or, in other words, the thickness is the same along its whole length. The distance between the horizontal lines must be measured, but the position of the vertical lines can be found by drawing vertical projection lines with the T-square and triangle, through the different points on the top view. Draw the fillets between the head and handle with a radius equal to one-half of $(E - F)$.

Put on the dimensions that you have calculated and not the letters shown in Fig. 50.

The drop forging of which this wrench is made differs from the forging hammered out by hand in the ordinary blacksmith shop in that, after the steel is heated to the proper temperature, it is placed on a "die" or a block of steel hollowed out to the exact shape that the wrench is to be, but only

half deep enough for it. A second die similar to the first is fastened to the bottom of a heavy weight which slides between vertical guides. The weight is pulled up and then allowed to drop; this is repeated as many times as is necessary until the metal that was placed on the lower die is formed between the two dies into the desired shape. Drop forgings are much smoother than other forgings and require little finishing, except when pieces go together. On this wrench only the opening and the faces of the jaw are to be machined or finished.

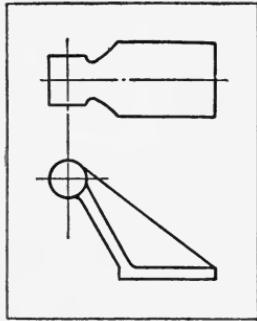


FIG. 53.

ASSIGNMENT 6

Problem 6

Fig. 52 shows a side and end view of a cast-iron bracket such as is used to support the camshaft on a horizontal gas engine. It consists of a flat rectangular plate with four holes drilled through it, an arm strengthened by a deep rib, and a hub on the end bored for the camshaft. The bracket is fastened to a planed spot on the base of the engine by four $\frac{1}{4}$ -in. cap screws through the holes in the base of the bracket.

The views shown here are not the best. The bracket would be shown to better advantage if the top view were drawn instead of the end view. The student is to make a pencil drawing of this bracket using the side view and the top view. In Fig. 53 are shown roughly the views wanted. The student should make the drawing full size, using a 9-in. \times 12-in. sheet, placed with the 12-in. dimension vertical on the board.

CHAPTER II

SCREWS AND SCREW FASTENINGS

ASSIGNMENT 7

20. Screw Measurements.—*The Nominal or Outside Diameter.*—The nominal diameter of any screw or bolt is the diameter at the top or outside of the threads. By nominal diameter we mean the diameter by which the bolt is known. This is the diameter given in the first column of the bolt table, page 35. Thus, a $\frac{5}{8}$ -in. bolt measures $\frac{5}{8}$ in. in diameter at the top or outside of the threads.

The Root or Effective Diameter.—The root diameter of a screw is the diameter at the bottom or root of the threads. This is

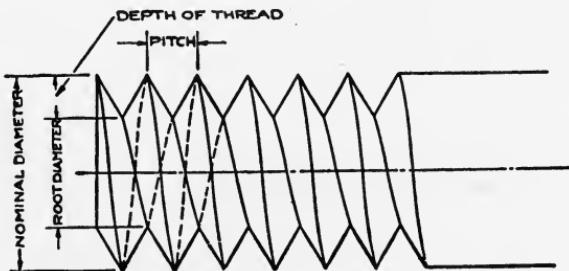


FIG. 54.

the dimension from which the strength of the screw is calculated, because it is the smallest diameter and hence the weakest. The nominal and root diameters are shown in Fig. 54.

Depth of Thread.—The depth of the thread is the radial distance between the top and bottom of the threads; that is, measured in a direction straight outward from the center.

21. Forms of Threads.—The most common thread forms are the V, U. S. standard, Square, Acme, Worm, and Whitworth. Other shapes may be designed to meet special conditions. Fig. 55 shows the outlines of the above-named threads.

The V Thread.—The V thread has an angle of 60° between the sides and is pointed at the top and bottom. Its use is confined chiefly to small screws.

The U. S. Standard Thread.—The United States standard thread was designed by Mr. William Sellers of Philadelphia and recommended by the Franklin Institute of that city in 1864. It was later adopted in a modified form by the U. S. Government and is now variously known as the Sellers, the Franklin Institute, and the U. S. standard thread. It is similar to the V thread with the exception that the top and bottom of the thread are flat, thus leaving a larger root diameter and therefore making a stronger bolt than if the V thread were used. It is used generally for bolts, studs and cap screws. The width of the flat surface at the top and bottom of the threads is one-eighth of the pitch.

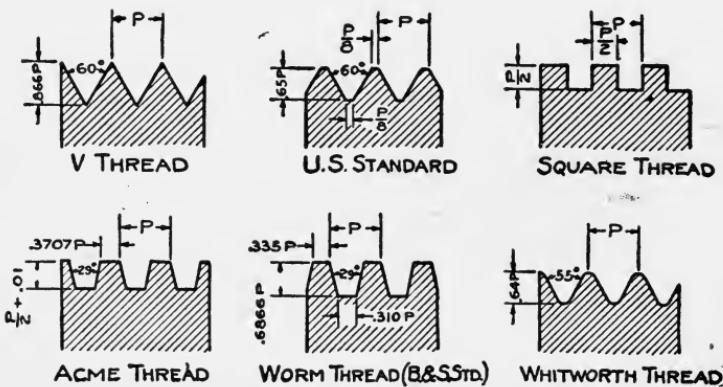


FIG. 55.

The Square Thread.—The Square thread has not been standar-dized. It is used for heavy work to transmit motion or power, as in jack screws and screw presses, but each manufacturer has his own standards of pitch. It is quite common practice to use a pitch twice as great as on a U. S. standard bolt of the same diameter. The Square thread is more difficult to cut than the other forms of threads.

The Acme Thread.—The Acme thread is a compromise between the Square and U. S. standard threads. It is as deep as the square thread, but is stronger and easier to cut. It is used a great deal for feed screws, lead screws, etc., on lathes and other machine tools.

The Worm Thread (Brown and Sharpe Standard).—This is used for the threads of worms in worm and wormwheel combinations. It is really a form of gearing, but is cut in a lathe and is therefore given the name of *thread*. It is a much deeper

thread than the Acme, with the same angle (29°) between the sides of the threads.

The Whitworth Thread.—The Whitworth thread is the standard used in England. It was designed by Sir Joseph Whitworth in 1841, but has been slightly modified since that time. It is more difficult to form than either the V or the U. S. standard, as the thread tools must be ground so as to make the exact curves at the top and bottom.

22. Pitch.—Usually the threading of a bolt or screw is described by telling the number of threads per 1 in. of length, thus—"8 threads per inch," or simply "8 pitch." However, in giving the proportions of any given thread, we usually describe them in terms of the *pitch*. This is the distance from any point of a thread to the corresponding point on the next thread, as shown in Fig. 54, and is designated by the letter *P*, as shown in Fig. 55. The pitch of a single-threaded screw is the distance the screw or nut will advance in one complete turn. Thus a screw having 8 threads per inch has a pitch of $\frac{1}{8}$ in. and would advance $\frac{1}{8}$ in. in one complete turn.

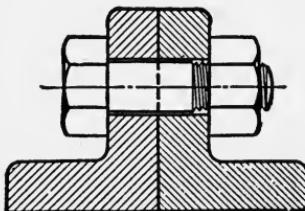


FIG. 56.

23. Bolts.—A bolt is a bar with a head on one end and a thread for a nut on the other. It is used to fasten two parts together by passing through them and clasping them together between the head and nut, as shown in the case of the two angles of Fig. 56. Unless otherwise stated, it is understood that bolts have the U. S. standard thread, as this thread is in common use by bolt manufacturers. Bolts are designated by the shape of the head. The kinds usually employed in machine work are the square head and the hexagon (or "hex") head machine bolts (Figs. 57 and 59). The round or bar length of the bolt is called the *stock*, and carries on its end the thread for the nut. There are numerous special kinds of bolts used in special industries; for example, there are plow bolts, carriage bolts, stove bolts, etc.

24. Bolt Heads and Nuts.—The heads and nuts of machine bolts may be either square or hexagonal, as desired. These have the same principal dimensions so that the same wrenches can be used on either. Table A shows the dimensions of the U. S. standard rough-forged nuts and heads. Finished heads and

| DIMENSIONS OF U.S. STANDARD BOLTS, HEADS, & NUTS. | | | | | | | | |
|---|-------------------------|---|-------------------------------|----------------------------|-------------------|-----------------|------------------|-------|
| ROUGH. | | | | | | | | |
| DIA. OF BOLT | NO. OF THREADS PER INCH | SHORT DIA. OF HEADS & NUTS HEX. & SQ | LONG DIAMETER OF HEADS & NUTS | THICKNESS HEXAGON & SQUARE | DIA. OF TAP DRILL | ROOT DIAMETER | | |
| $\frac{1}{4}$ | 20 | $\frac{1}{2}$ | $\frac{37}{64}$ | $\frac{23}{32}$ | $\frac{1}{4}$ | $\frac{13}{64}$ | .185 | |
| $\frac{5}{16}$ | 18 | $\frac{19}{32}$ | $\frac{11}{16}$ | $\frac{27}{32}$ | $\frac{19}{64}$ | $\frac{1}{4}$ | .240 | |
| $\frac{3}{8}$ | 16 | $\frac{11}{16}$ | $\frac{51}{64}$ | $\frac{31}{32}$ | $\frac{11}{32}$ | $\frac{3}{8}$ | .294 | |
| $\frac{7}{16}$ | 14 | $\frac{25}{32}$ | $\frac{29}{32}$ | $\frac{7}{64}$ | $\frac{25}{64}$ | $\frac{7}{16}$ | $\frac{23}{64}$ | .344 |
| $\frac{1}{2}$ | 13 | $\frac{7}{8}$ | $1\frac{1}{64}$ | $1\frac{1}{4}$ | $\frac{7}{16}$ | $\frac{1}{2}$ | $\frac{27}{64}$ | .400 |
| $\frac{9}{16}$ | 12 | $\frac{31}{32}$ | $1\frac{1}{8}$ | $1\frac{3}{8}$ | $\frac{31}{64}$ | $\frac{9}{16}$ | $\frac{15}{32}$ | .454 |
| $\frac{5}{8}$ | 11 | $1\frac{1}{16}$ | $1\frac{15}{64}$ | $1\frac{1}{2}$ | $\frac{17}{32}$ | $\frac{5}{8}$ | $\frac{17}{32}$ | .507 |
| $\frac{3}{4}$ | 10 | $1\frac{1}{4}$ | $1\frac{29}{64}$ | $1\frac{25}{32}$ | $\frac{5}{8}$ | $\frac{3}{4}$ | $\frac{41}{64}$ | .620 |
| $\frac{7}{8}$ | 9 | $1\frac{7}{16}$ | $1\frac{43}{64}$ | $2\frac{1}{32}$ | $\frac{23}{32}$ | $\frac{7}{8}$ | $\frac{3}{4}$ | .731 |
| 1 | 8 | $1\frac{5}{8}$ | $1\frac{7}{8}$ | $2\frac{19}{64}$ | $\frac{13}{16}$ | 1 | $\frac{55}{64}$ | .837 |
| $1\frac{1}{8}$ | 7 | $1\frac{13}{16}$ | $2\frac{3}{32}$ | $2\frac{9}{16}$ | $\frac{29}{32}$ | $1\frac{1}{8}$ | $\frac{31}{32}$ | .940 |
| $1\frac{1}{4}$ | 7 | 2 | $2\frac{5}{16}$ | $2\frac{53}{64}$ | 1 | $1\frac{1}{4}$ | $1\frac{3}{32}$ | 1.065 |
| $1\frac{3}{8}$ | 6 | $2\frac{3}{16}$ | $2\frac{17}{32}$ | $3\frac{3}{32}$ | $1\frac{3}{32}$ | $1\frac{3}{8}$ | $1\frac{13}{64}$ | 1.160 |
| $1\frac{1}{2}$ | 6 | $2\frac{3}{8}$ | $2\frac{3}{4}$ | $3\frac{23}{64}$ | $1\frac{3}{16}$ | $1\frac{1}{2}$ | $1\frac{21}{64}$ | 1.284 |
| $1\frac{3}{4}$ | 5 | $2\frac{3}{4}$ | $3\frac{3}{16}$ | $3\frac{57}{64}$ | $1\frac{3}{8}$ | $1\frac{3}{4}$ | $1\frac{17}{32}$ | 1.491 |
| 2 | $4\frac{1}{2}$ | $3\frac{1}{8}$ | $3\frac{39}{64}$ | $4\frac{27}{64}$ | $1\frac{9}{16}$ | 2 | $1\frac{3}{4}$ | 1.712 |
| $2\frac{1}{4}$ | $4\frac{1}{2}$ | $3\frac{1}{2}$ | $4\frac{3}{64}$ | $4\frac{61}{64}$ | $1\frac{3}{4}$ | $2\frac{1}{4}$ | 2 | 1.962 |
| $2\frac{1}{2}$ | 4 | $3\frac{7}{8}$ | $4\frac{61}{64}$ | $5\frac{31}{64}$ | $1\frac{15}{16}$ | $2\frac{1}{2}$ | $2\frac{7}{32}$ | 2.176 |
| $2\frac{3}{4}$ | 4 | $4\frac{1}{4}$ | $4\frac{29}{32}$ | $6\frac{1}{64}$ | $2\frac{1}{8}$ | $2\frac{3}{4}$ | $2\frac{15}{32}$ | 2.426 |
| 3 | $3\frac{1}{2}$ | $4\frac{5}{8}$ | $5\frac{11}{32}$ | $6\frac{17}{32}$ | $2\frac{5}{16}$ | 3 | $2\frac{11}{16}$ | 2.629 |

TABLE A

nuts are $\frac{1}{16}$ in. smaller in width than the dimensions given here.

In representing a bolt head or nut on a drawing, we do not go to the trouble to lay it out precisely from the dimensions given in the table, unless the bolt itself is the main part of the drawing. If the bolt is only a detail of the drawing we generally use a simple system which represents very nearly the exact sizes and saves much time in drawing. In Figs. 57, 58, 59 and 60 are shown the different views of square and hexagon bolt heads as they are usually drawn. The views of Figs. 57 and 59 are usually preferred because they indicate more clearly in the elevation that the heads are square or hexagonal. Figs. 58 and 60 both have

SQUARE HEAD BOLT.

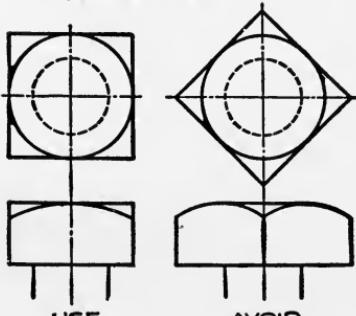


FIG. 57.

FIG. 58.

HEXAGONAL HEAD BOLT.

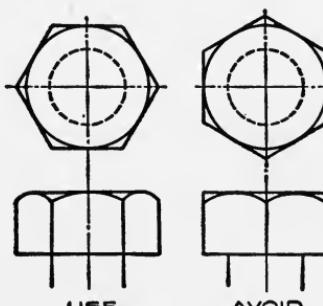


FIG. 59.

FIG. 60.

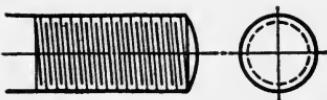
two faces showing in the elevation and therefore might be confused.

In drawing the square head of Fig. 57 the width of the square is made about one and three-fourths times the bolt diameter. The draftsman does this by eye. The height of the head in the front elevation is made half the width of the head or a little less than the bolt diameter. The height of a nut is made the same as the bolt diameter. The chamfer (the bevelling of the corners on top) is shown by the full circle in the top view. In the front view we represent this by an arc, with radius equal to the width of the head, drawn tangent to the top of the head.

To represent the hexagonal head or nut (Fig. 59) the draftsman extends the lines representing the bolt stock. This gives one face of the head in the front elevation. One-half this width is set out on each side, for the other two visible faces. The top

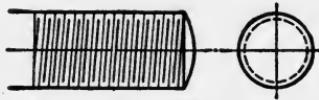
line is next drawn at a height a little less than the bolt diameter. The chamfer is then shown. In the front face this is drawn with a radius equal to the bolt diameter. On the side faces a radius about one-third as great is used. In drawing the top view of a hexagon head, we locate the center lines and draw a broken circle to represent the stock of the bolt. With the diameter of the bolt as a *radius* we then draw a light construction circle, and in this we draw a hexagon. We then erase the construction circle. Within the hexagon and just touching each side of it, we draw a circle to represent the chamfering or bevel on the top corners.

25. Thread Conventions.—Draftsmen usually show threads in side view by the conventional straight-line method shown in Figs. 61 and 62. The long light lines represent the tops or "lands" of the thread while the short heavy lines represent the bottoms or "roots" of the thread. These lines should be evenly



R. H. THREAD.

FIG. 61.



L. H. THREAD.

FIG. 62.

spaced and should be given a slight slant. On a single-threaded screw, one end of a light line should lie approximately opposite the other end of its adjacent heavy line. Ordinarily no attempt is made to make the spacing of these lines comply exactly with the pitch of the screw.

The method of representing the end view of a screw is also shown in Figs. 61 and 62. The circle representing the "lands" of the threads is drawn solid, while the root circle is broken because it represents a hidden surface, namely, the bottom of the thread.

26. Right-hand and Left-hand Threads.—The thread shown in Fig. 61 is a right-hand thread; that is, to screw a nut on to such a thread it would be necessary to turn it in a right-hand or clockwise direction. Compare this with Fig. 62, which shows a left-hand thread. Note that the thread lines in this figure are given a slant opposite to those shown in Fig. 61. Where the stock of the bolt ends, a heavy object line should always be shown as in these figures. At the place where the thread termi-

nates a light line should be drawn straight across the bolt. The end of the stock should always be rounded, but its length should only be dimensioned to the corner where the rounded end begins and not to the extreme tip of the bolt.

Left-hand threads are not nearly so common as right-hand threads; hence, when a left-hand thread is desired it should be marked, *L. H. Thread*. It is not generally customary to mark right-hand threads as such; if marked, we would use the note, *R. H. Thread*.

27. Tapped Holes.—The thread which is cut in any piece of metal to receive a screw is said to be "tapped." Ordinarily a hole is drilled in the piece to the same diameter as the inner

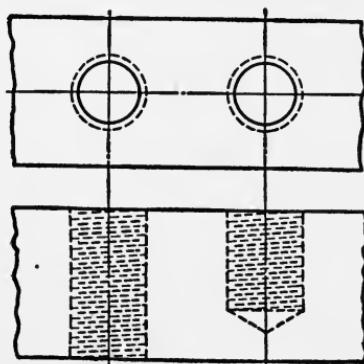


FIG. 63.

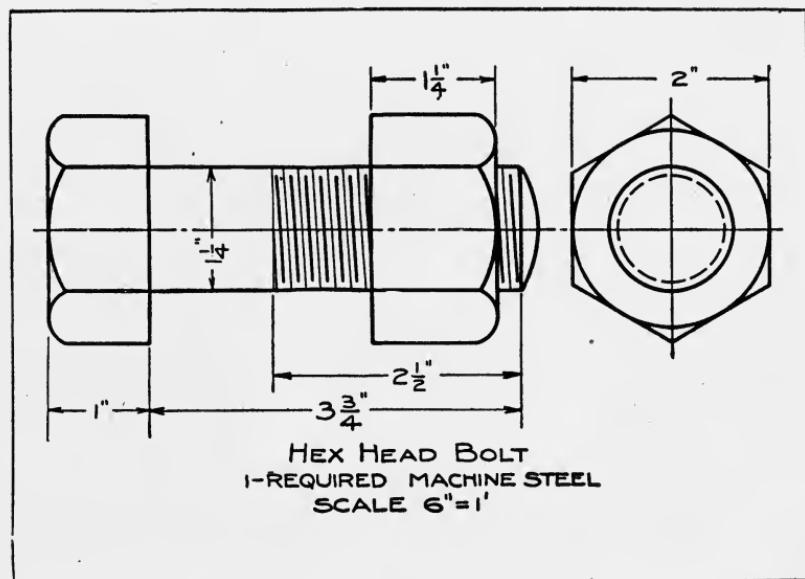


FIG. 64.

diameter of the thread. A "tap" (which is somewhat like a hardened bolt, having grooves for the cut metal to escape and

sharp cutting edges on its threads) is then screwed into this hole, cutting a thread as it advances.

In representing a tapped hole in a drawing, the plan view of the hole is very simple. As shown in Fig. 63, the plan view shows a solid inner circle representing the hole drilled for the tap; a broken outer circle surrounds it to represent the hidden threads cut by the tap. This outer circle is drawn to the nominal diameter of the screw.

The representation of a tapped hole in elevation must naturally be all in broken lines, since the hole is hidden from sight in this view. Fig. 63 illustrates the most common method of

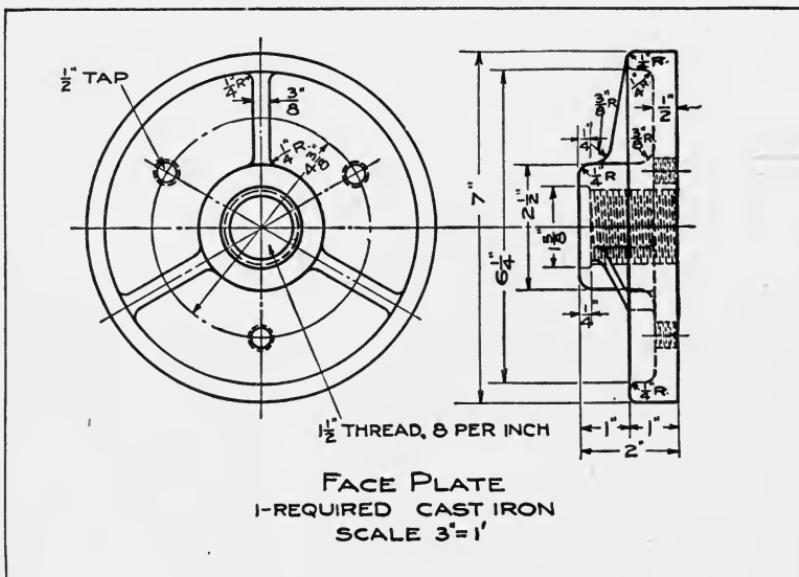


FIG. 65.

showing this. The threads are represented just as in Fig. 61, but with all broken lines. The hole at the left is drilled and tapped clear through the piece; that at the right, only part way through.

Fig. 64 shows a drawing of a $1\frac{1}{4}$ -in. \times $3\frac{3}{4}$ -in. hex. head machine bolt with nut, using the conventional methods of showing the threads and the head and nut. The actual heights of head and nut and the true width (from Table A) are given for the guidance of the blacksmith and machinist in making the bolt.

Fig. 65 shows a drawing involving several tapped holes. This

is a special face plate for a lathe. It is to be tapped with a $\frac{1}{2}$ -in. standard bolt tap at three points equally spaced on a circle of $4\frac{3}{8}$ -in. diameter. These holes are for studs for attaching a special fixture to the face plate. In the center of the plate is an internal thread for screwing the face plate onto the spindle. The note referring to this hole is marked *THREAD* instead of *TAP*,

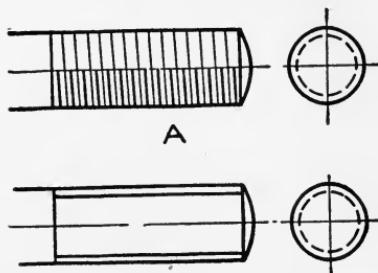


FIG. 66.

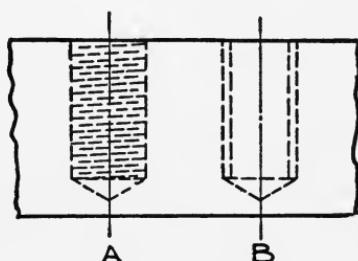


FIG. 67.

because this is to be cut with a thread tool in a lathe in order to make it absolutely true.

28. Other Thread Conventions.—In Figs. 66 and 67 are shown other conventions that are occasionally seen. The convention at *B* in these figures is especially simple and convenient for sketching purposes but has the great disadvantage that

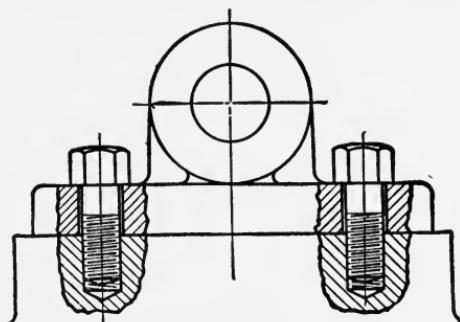


FIG. 68.

it bears no resemblance to screw threads and hence is not recommended.

29. Cap Screws.—A cap screw is similar to a bolt, but is used without a nut. The head may be either square or hexagonal. A cap screw is used by passing it through one of the pieces to be fastened together and screwing the threaded part into the other piece. Fig. 68 shows the method of using cap screws in fastening

**DIMENSIONS OF A.S.M.E. STANDARD
MACHINE SCREWS**

| NO. | THREADS PER INCH | DIAMETER OF BODY | DIAM. OF FLAT HEAD | DIAM. OF ROUND HEAD | DIAM. OF FILLISTER HEAD | LENGTHS |
|-----|---------------------|---------------------|-----------------------|------------------------|----------------------------|------------------------------------|
| 0 | 80 | .060 | .112 | .106 | .0894 | $\frac{1}{8}$ " TO $\frac{3}{8}$ " |
| 1 | 72 | .073 | .138 | .130 | .1107 | $\frac{1}{8}$ " " $\frac{3}{8}$ " |
| 2 | 64 | .086 | .164 | .154 | .1320 | $\frac{3}{16}$ " " $\frac{1}{2}$ " |
| 3 | 56 | .099 | .190 | .178 | .1530 | $\frac{3}{16}$ " " $\frac{5}{8}$ " |
| 4 | 48 | .112 | .216 | .202 | .1747 | $\frac{3}{16}$ " " $\frac{3}{4}$ " |
| 5 | 44 | .125 | .242 | .226 | .1960 | $\frac{3}{16}$ " " $\frac{7}{8}$ " |
| 6 | 40 | .138 | .262 | .250 | .2170 | $\frac{3}{16}$ " " 1" |
| 7 | 36 | .151 | .294 | .274 | .2386 | $\frac{1}{4}$ " " $\frac{1}{8}$ " |
| 8 | 36 | .164 | .320 | .298 | .2599 | $\frac{1}{4}$ " " $\frac{1}{4}$ " |
| 9 | 32 | .177 | .346 | .322 | .2813 | $\frac{1}{4}$ " " $\frac{3}{8}$ " |
| 10 | 30 | .190 | .372 | .346 | .3026 | $\frac{1}{4}$ " " $\frac{1}{2}$ " |
| 12 | 28 | .216 | .424 | .394 | .3452 | $\frac{3}{8}$ " " $1\frac{3}{4}$ " |
| 14 | 24 | .242 | .472 | .443 | .3879 | $\frac{3}{8}$ " " 2" |
| 16 | 22 | .268 | .528 | .491 | .4305 | $\frac{3}{8}$ " " $2\frac{1}{4}$ " |
| 18 | 20 | .294 | .580 | .539 | .4731 | $\frac{1}{2}$ " " $2\frac{1}{2}$ " |
| 20 | 20 | .320 | .632 | .587 | .5158 | $\frac{1}{2}$ " " $2\frac{3}{4}$ " |
| 22 | 18 | .346 | .682 | .635 | .5584 | $\frac{1}{2}$ " " 3" |
| 24 | 16 | .372 | .732 | .683 | .6010 | $\frac{1}{2}$ " " 3" |
| 26 | 16 | .398 | .788 | .731 | .6437 | $\frac{3}{4}$ " " 3" |
| 28 | 14 | .424 | .840 | .779 | .6863 | $\frac{7}{8}$ " " 3" |
| 30 | 14 | .450 | .892 | .827 | .7270 | 1" " 3" |

TABLE B.

a bracket to a machine. In this figure, the metal around the cap screw is broken away to show the cap screw clearly.

The heads of cap screws are smaller than those of bolts. The widths (or the short diameters) of hexagon heads for cap screws are standardized as follows:

For screws up to and including $\frac{1}{8}$ in., the heads are made $\frac{3}{16}$ in. wider than the screw stock.

For sizes $\frac{1}{2}$ in. and larger, the heads are made $\frac{1}{4}$ in. wider than the screw stock.

For square heads, the width is $\frac{1}{8}$ in. greater than the stock for sizes up to and including $\frac{3}{4}$ in. Above $\frac{3}{4}$ in. the heads are $\frac{1}{4}$ in.

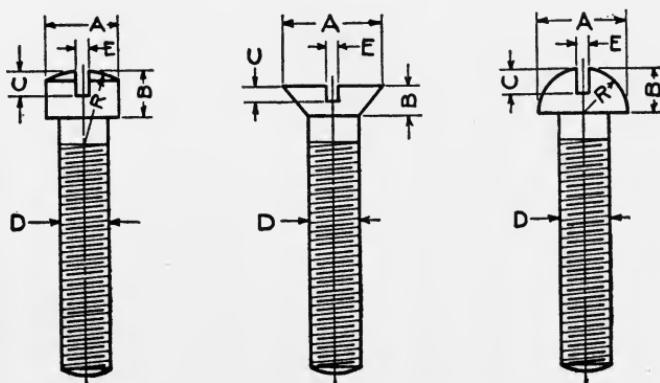


FIG. 69.

wider than the stock diameter. The height of the head is equal to the diameter of the screw. The top of the head is not flat like a bolt head, but is rounded with a radius equal to the long diameter of the head. Cap screws can also be obtained with any of the other heads shown in Fig. 70.

30. Machine Screws.—Machine screws are used for the same purpose as cap screws, but for small work only. Machine screws are generally used for sizes below $\frac{1}{4}$ in. They are made in screw gage sizes and sold by the gage numbers instead of the fractional inch sizes.

Table B gives the dimensions of standard machine screws. The lengths given in the last column are the distances that the screws will enter the work, which are the lengths under the head, except in the cases of the Flat and French heads, where they are the overall dimensions.

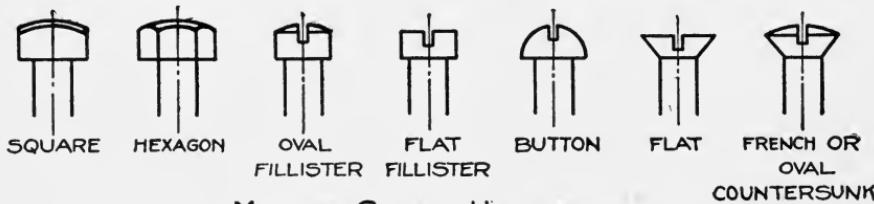
For drawing the heads of machine screws the following dimen-

sions for Fig. 69 may be used, although they do not check exactly with those of Table *B*:

| | Fillister Head | Flat Head | Round Head |
|-------|------------------|------------------|------------------|
| $D =$ | Diameter of body | Diameter of body | Diameter of body |
| $A =$ | $1.5 D$ | $2.0 D$ | $1.75D$ |
| $B =$ | $0.75D$ | $0.6 D$ | $0.5 A$ |
| $C =$ | $0.5 D$ | $0.3 D$ | $0.5 D$ |
| $E =$ | $0.25D$ | $0.25D$ | $0.25D$ |
| $R =$ | A | | $0.5 A$ |

Fig. 70 shows some of the different kinds of heads for machine screws. The square and hexagonal heads are the only ones on which a wrench can be used. These heads are usually thicker and of smaller diameter than the U. S. standard bolt heads. All of the other heads are provided with slots for a screw driver.

31. Set Screws.—A set screw is used to fasten two machine parts together by screwing through one part and pressing against the other. For example, in fastening a wheel to a shaft, the set



MACHINE SCREW HEADS.

FIG. 70.

screw passes through the hub of the wheel and presses against the shaft. It is a poor fastening for transmitting power, and should not be used if a key or square shaft can be used.

Fig. 71 shows some of the common forms of heads for set screws. The thickness of the head and the width across the flats are ordinarily made equal to the diameter of the screw. The headless set screw, in which a screw driver is used to turn it into place has the advantage that it can be screwed in so that there are no projecting parts to catch the clothing. It has the objection, however, that one side is apt to break off. To remedy this defect, a hollow-head set screw has been designed. This requires a special wrench bent from a hexagon steel bar.

Set screws are sometimes "necked" under the head. This is

done by cutting them down so that the diameter is a little less than that of the root of the thread. This makes the "neck" the weakest part of the screw so that, if the screw should break when being tightened, it will break at the neck instead of in the hole.

The most common forms of set screw points are shown in Fig. 72. Any of the heads of Fig. 71 can be used with any of these

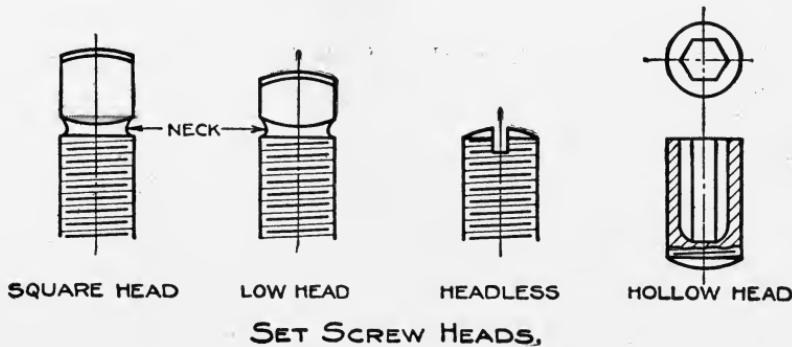


FIG. 71.

points. In using a set screw on finished work, where the point of the screw is liable to burr or roughen the part against which it presses, a round brass piece called a "gib" is often dropped into the tapped hole so that the screw point presses against the gib and the gib against the part to be fastened. Set screws are made of steel and are usually case-hardened.

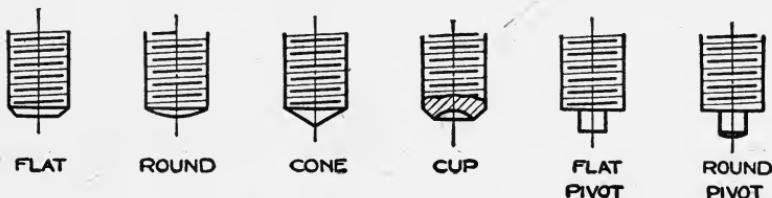


FIG. 72.

32. Multiple Threads.—In all of the threads that we have considered thus far, there has been but a single thread on the screw. It is sometimes desirable, however, to have more than one. If there are two separate threads on the screw, it is called a *double thread*; if three threads, a *triple thread*; and if there are four threads, it is a *quadruple thread*.

In Fig. 73 is shown a double-thread screw. Compare it with Fig. 54. The outside diameter of the screw, the root diameter, the depth of the threads, and the pitch are the same in both cases, but the amount that the thread advances in one turn or revolution of the screw is twice as great in the double thread as in the single thread, and the lines of the threads in the drawings must be given a correspondingly greater slant than in the case of single threads.

33. Lead.—The distance that the thread advances along the screw per revolution is called the *lead* (pronounced as if spelled "leed"). For a triple thread, the lead would be three times the pitch. Multiple threads are used when it is desired to secure a greater advance per revolution, without reducing the root diameter of the screw. Any of the threads of Fig. 55 may be

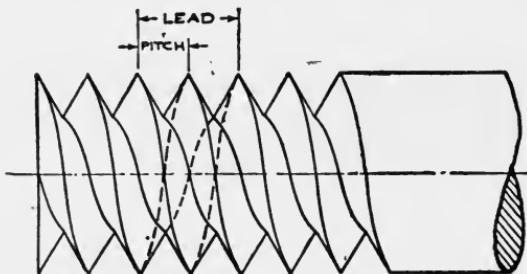


FIG. 73.

made multiple. Wherever a multiple thread appears on a drawing, a note should state the fact, giving complete information.

Problem 7

Make a full-size pencil drawing of the details shown in Fig. 74. Use a 9-in. \times 12-in. sheet. First lay out all of the center lines and then draw the machine screws. As is noted on the sketch, these are to be No. 24 screws with 16 threads per inch. Refer to Table B, which is the table of standards adopted by the American Society of Mechanical Engineers, and you will find that the diameter of the body of a No. 24 screw is 0.372 in. For drawing the heads, use the proportions given with Fig. 69, but do not put any dimensions on the heads.

The dimensions that you get will be in decimals and, if you have no scale divided into hundredths of an inch, you can find the nearest fraction from Table C, and use the ordinary scale. For example, the diameter of the body of a No. 24 screw is 0.372 in. The decimal in Table C that is nearest to this is 0.375 which is the equivalent of $\frac{3}{8}$ in. Use $\frac{3}{8}$ in. for the diameter of the

screws when drawing them, but use 0.372 in. when making your calculations.

The length of each of the screws, exclusive of the head, is $1\frac{1}{2}$ in. This dimension, together with the number of the screw and the threads per inch, is all of the information necessary on the drawing.

Use the method of Fig. 61 for drawing the threads for all of the details on this sheet.

Next draw the bolt. Obtain the dimensions of the head and nut from Table A. Be sure to supply the two dimensions for the nut.

Finally, draw the square-head cap screw. The head of this screw is smaller than that of a bolt but is higher. The dimensions can be obtained from the following:

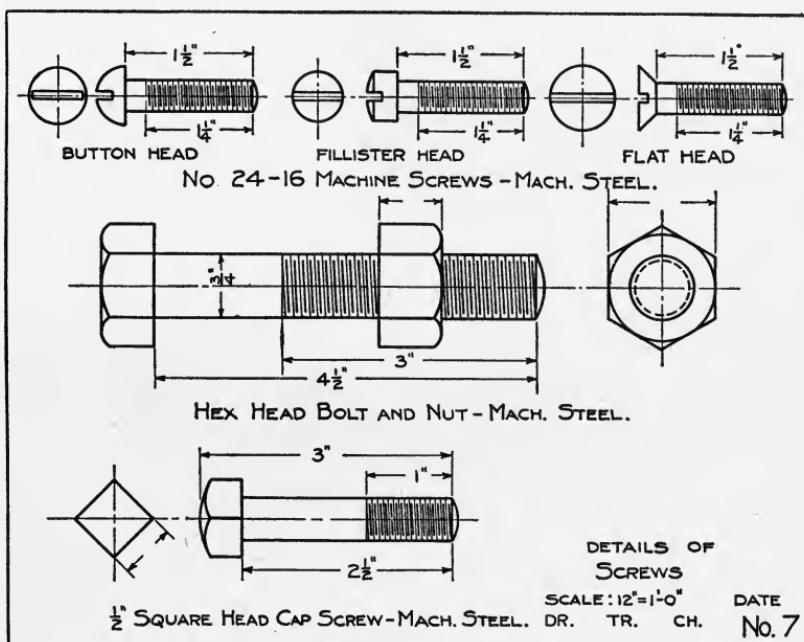


FIG. 74.

The short diameter of a square head for a cap screw is $\frac{1}{8}$ in. greater than the diameter of the screw, for sizes of screw up to and including $\frac{3}{8}$ in. For screws $\frac{3}{8}$ in. and larger, the short diameter of the head is $\frac{1}{4}$ in. greater than the diameter of the screw. The short diameter of a hexagonal head for a cap screw is $\frac{3}{16}$ in. greater than the diameter of the screw, for sizes of screw up to and including $\frac{7}{16}$ in. For screws $\frac{1}{2}$ in. and larger, the short diameter of the head is $\frac{1}{4}$ in. greater than the diameter of the screw. The height of either a square or hexagonal head for a cap screw is equal to the diameter of the screw. The top of the head, in either case, is rounded with a radius equal to the long diameter of the head.

Put the title under each of the parts and the general title in the lower right-hand corner of the sheet as shown in the figure.

TABLE OF DECIMAL EQUIVALENTS FROM $\frac{1}{64}$ TO 1 INCH

| FRACTION | DECIMAL EQUIVALENT | FRACTION | DECIMAL EQUIVALENT |
|-----------------|--------------------|-----------------|--------------------|
| $\frac{1}{64}$ | .015625 | $\frac{33}{64}$ | .515625 |
| $\frac{1}{32}$ | .03125 | $\frac{17}{32}$ | .53125 |
| $\frac{3}{64}$ | .046875 | $\frac{35}{64}$ | .546875 |
| $\frac{1}{16}$ | .0625 | $\frac{9}{16}$ | .5625 |
| $\frac{5}{64}$ | .078125 | $\frac{37}{64}$ | .578125 |
| $\frac{3}{32}$ | .09375 | $\frac{19}{32}$ | .59375 |
| $\frac{7}{64}$ | .109375 | $\frac{39}{64}$ | .609375 |
| $\frac{1}{8}$ | .125 | $\frac{5}{8}$ | .625 |
| $\frac{9}{64}$ | .140625 | $\frac{41}{64}$ | .640625 |
| $\frac{5}{32}$ | .15625 | $\frac{21}{32}$ | .65625 |
| $\frac{11}{64}$ | .171875 | $\frac{43}{64}$ | .671875 |
| $\frac{3}{16}$ | .1875 | $\frac{11}{16}$ | .6875 |
| $\frac{13}{64}$ | .203125 | $\frac{45}{64}$ | .703125 |
| $\frac{7}{32}$ | .21875 | $\frac{23}{32}$ | .71875 |
| $\frac{15}{64}$ | .234375 | $\frac{47}{64}$ | .734375 |
| $\frac{1}{4}$ | .25 | $\frac{3}{4}$ | .75 |
| $\frac{17}{64}$ | .265625 | $\frac{49}{64}$ | .765625 |
| $\frac{9}{32}$ | .28125 | $\frac{25}{32}$ | .78125 |
| $\frac{19}{64}$ | .296875 | $\frac{51}{64}$ | .796875 |
| $\frac{5}{16}$ | .3125 | $\frac{13}{16}$ | .8125 |
| $\frac{21}{64}$ | .328125 | $\frac{53}{64}$ | .828125 |
| $\frac{11}{32}$ | .34375 | $\frac{27}{32}$ | .84375 |
| $\frac{23}{64}$ | .359375 | $\frac{55}{64}$ | .859375 |
| $\frac{3}{8}$ | .375 | $\frac{7}{8}$ | .875 |
| $\frac{25}{64}$ | .390625 | $\frac{57}{64}$ | .890625 |
| $\frac{13}{32}$ | .40625 | $\frac{29}{32}$ | .90625 |
| $\frac{27}{64}$ | .421875 | $\frac{59}{64}$ | .921875 |
| $\frac{7}{16}$ | .4375 | $\frac{15}{16}$ | .9375 |
| $\frac{29}{64}$ | .453125 | $\frac{61}{64}$ | .953125 |
| $\frac{15}{32}$ | .46875 | $\frac{21}{32}$ | .96875 |
| $\frac{31}{64}$ | .484375 | $\frac{63}{64}$ | .984375 |
| $\frac{1}{2}$ | .5 | 1. | .00000 |

TABLE C.

ASSIGNMENT 8

34. Method of Drawing Square Threads.—In order to show a square thread accurately it would be necessary to show the threads curved as in Fig. 75. For shop drawings this is not necessary, however, and the straight-line conventional method of Fig. 76 may be used.

To lay out threads by this method, space off points on one

side of the screw so that the thickness of thread and width of space are equal; in other words, the points are equally spaced. Then space off points on the other side of the screw so that they are opposite the ones first drawn, as indicated by the dotted lines of Fig. 76, which are drawn perpendicular to the center line of the screw. For a single thread, the lines drawn across the screw should be drawn so that a space on one side comes opposite a thread on the other. The threads shown in the figure represent

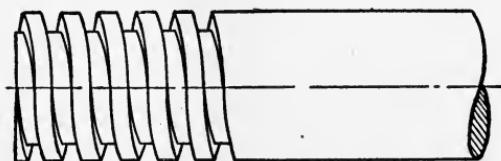


FIG. 75.

a single thread. If the thread were double, a space would come opposite a space and the lines would slant still more.

35. Drawing to Scale.—In representing objects which are larger than the allowable drawing space, it is necessary to reduce the dimensions proportionately. This is accomplished by the use of the architect's scale, shown in Fig. 20. This scale usually bears eleven different graduations, as follows:

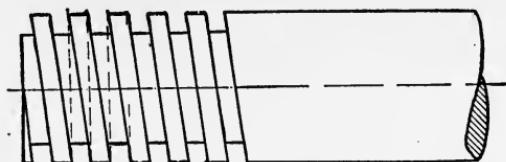


FIG. 76.

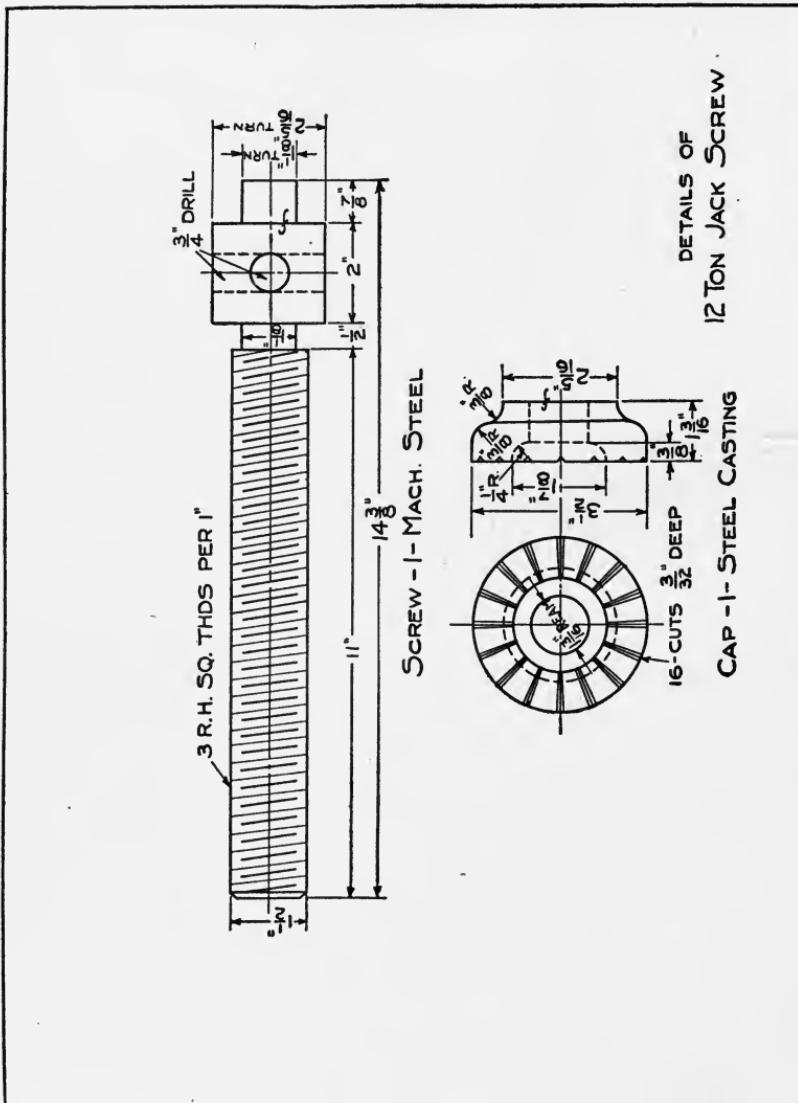
Full size

| |
|----------------------|
| Scale 3 in. = 1 ft. |
| Scale 1½ in. = 1 ft. |
| Scale 1 in. = 1 ft. |
| Scale ¾ in. = 1 ft. |
| Scale ½ in. = 1 ft. |

| |
|----------------------------------|
| Scale $\frac{3}{8}$ in. = 1 ft. |
| Scale $\frac{1}{4}$ in. = 1 ft. |
| Scale $\frac{3}{16}$ in. = 1 ft. |
| Scale $\frac{1}{8}$ in. = 1 ft. |
| Scale $\frac{3}{32}$ in. = 1 ft. |

The first reduction in size in common use is half-size, or to the scale of 6 in. = 1 ft. This scale is not shown on the architects' scale, but is easily taken from the full-size scale. Each dimension on a half-size drawing is reduced one-half of full-size. If this scale is too large, the next one to use is 3 in. = 1 ft., or

quarter-size. On this scale a distance of 3 in. is divided into twelve equal parts, and each of these into eight equal parts. In



Eng. 77.

using this scale, the student should think of the distance not as 3 in., but as a foot divided into inches and eighths of inches.

In drawing a circle, it is often convenient to lay off the diameter on a scale just half the size of the one to which the drawing is

made, and use this distance as a radius. For example, to draw a circle $1\frac{7}{8}$ in. diameter to a scale of 6 in. = 1 ft., lay off $1\frac{7}{8}$ in. on the scale of 3 in. = 1 ft., and use this distance as the radius.

Problem 8

Make a half-size pencil drawing of the screw and cap of a 12-ton jack screw, as shown in Fig. 77, drawing the views indicated in Fig. 78. Use a 9-in. \times 12-in. sheet for this drawing with the long dimension horizontal.

In drawing the screw, place the horizontal center line 2 in. below the upper border line. In the end view, place the vertical center line $\frac{3}{4}$ in. inside of the left vertical border line. Allow $\frac{5}{8}$ in. between these two views.

In drawing the cap, place the horizontal center line $4\frac{7}{8}$ in. below the upper border line. In the end view, place the vertical center line $2\frac{1}{2}$ in. to the right of the left vertical border line. Allow $\frac{3}{4}$ in. between the two views of the cap.

Use the Method of Fig. 76 for Showing the Square Threads of the Screw instead of the convention shown in the sketches of Fig. 77.

As there are three square threads per inch and as the width of space is the same as the thickness of the thread, each inch in

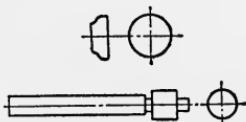


FIG. 78.



FIG. 79.

the drawing would be divided into six equal parts if the drawing were made *full-size*. Since the drawing is to be *half-size*, $\frac{1}{2}$ in. on the drawing equals 1 in. on the finished object; therefore, three complete threads or six equal spaces must be shown in a length of $\frac{1}{2}$ in. on the drawing in order that the threads as well as the rest of the drawing will be *half-size*. The length of each of these equal spaces is equal to one-sixth of $\frac{1}{2}$ in. or $\frac{1}{12}$ in. Since the scale is not divided into twelfths of an inch it is necessary to determine this length, $\frac{1}{12}$ in., in some manner. It might be determined by trial with the dividers by setting them to an approximate spacing of $\frac{1}{12}$ in. and then pointing off this distance twelve times along a straight line 1 in. long to determine how nearly correct the setting is. Another and better way to find the length of space without the use of the dividers is as follows: Draw a line exactly $\frac{1}{2}$ in. long, as the line A-B, Fig. 79. From

one end of it, as *A*, draw the line *A-C* of indefinite length and making an angle of about 30° with *A-B*. On *A-C*, starting at *A*, lay off six equal divisions. For these you can take any equal divisions, but $\frac{1}{4}$ in. is a convenient one. Lay off *A-1*, *1-2*, *2-3*, *3-4*, *4-5*, and *5-6*, each $\frac{1}{4}$ in. long. From *6* draw *6-B*. Parallel to *6-B* and through the points *5*, *4*, *3*, *2*, and *1*, draw the lines *5-5'*, *4-4'*, *3-3'*, *2-2'*, and *1-1'*.

The line *A-B*, $\frac{1}{2}$ in. long, is thus subdivided into six equal parts, each of which is equal to the width of space and the thickness of thread on the thread of the screw as it will appear upon the drawing. Any length of line can be divided into any number of equal parts in the same manner. The dividers can now be set to this spacing and the threads laid out on the screw.

The $\frac{3}{4}$ -in. holes in the largest diameter of the screw are for the purpose of inserting a bar to turn the screw.

Put a title or "legend" under each of the pieces, as shown in Fig. 77, in letters $\frac{1}{8}$ in. high. In the lower right-hand corner put the title of the plate,

DETAILS OF 12-TON JACK SCREW

as shown in Fig. 77, and make the balance of the title just as in the previous assignments.

CHAPTER III

SECTIONS

ASSIGNMENT 9

36. The Use of Sections.—The uses of broken lines to show hidden parts were explained in Chapter I, Art. 11. Broken lines are not always satisfactory and are often confusing, especially if very numerous. For these reasons, the method of showing objects *in section* is frequently used to show interior constructions. This method consists in cutting away the parts which hide those we want to show, thus allowing the hidden parts to stand out in full view. This is called *cross-sectioning*, or *sectioning*. Such a view is called a *cross-section*, or more simply, a *section*. As a simple illustration, we have in Fig. 80 two ordinary views of a plain cast-iron collar, the hole being indicated in the



FIG. 80.

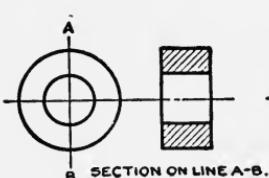


FIG. 81.

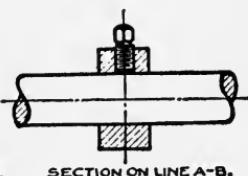


FIG. 82.

right view by the broken lines. Fig. 81 shows the same collar but with the hole shown by a *section* view. The end view is still shown in the usual manner, but, instead of the side view being shown by a front elevation, we imagine that the front half of the collar in this position has been cut away to show the inside. The light diagonal lines across the places where the metal would be cut form what is called the *cross-hatching*. These lines are drawn lightly about $\frac{1}{16}$ in. apart, and usually at an inclination of about 45° . If we imagine that the cross-hatching lines represent the saw marks, then we can always tell what part is to be cross-hatched. When there is a hole or opening in the object there will, of course, be no saw marks and, hence, there is no cross-hatching in the area representing such hole or opening, as is clearly shown in Fig. 81.

Let us suppose that this collar is fastened to a shaft by a set screw. In order to show the arrangement of the shaft and screw inside of the collar, we can cut the collar in the same way, as shown in Fig. 82. To actually cut the collar we would also have to saw into the shaft and screw, but it is customary to consider them as not being cut, as it would only increase the work of making the drawing and would not make the construction of the collar any clearer.

As a general rule it may be stated that: *Bolts, screws, shafts, keys, arms of pulleys, etc., are not shown in section when cut along the line of their greatest dimension, that is, lengthwise.* If the sec-

tion cuts across a shaft, screw, or similar object it might, in such a case, be cross-hatched.

Fig. 83 shows a section of a gland for a stuffing box. The flange around the top projects all the way around. Consequently, in the section elevation, the lower edge of the flange might be shown by a broken line crossing the body from *a* to *b*. It is much better, however, to keep the section free from such complications and only depend on it to show the interior of the object. If it is necessary to show both the inside and outside of the same view of

an object, it is better to use the principle of half-sections.

37. Half-sections.—When a figure is symmetrical about an axis (that is, alike on both sides of its center line), it is a good plan to show only one-half in section. Such a drawing is known as a "half-section" because we have only sawed halfway through. Fig. 84 shows a half-section of the same collar as in Fig. 82. In Fig. 84 we really consider that the upper front quarter of the collar is removed. The horizontal cut thus produces a surface along the horizontal center line, which is indicated by a heavy object line on the center line of Fig. 84. Any peculiarities of the outside of the object would be shown by one-half of the view, while the inside would be shown by the sectioned half of the view.

If a section passes through the center of a hole that is tapped—with a right-handed thread, the thread is shown in the conven-

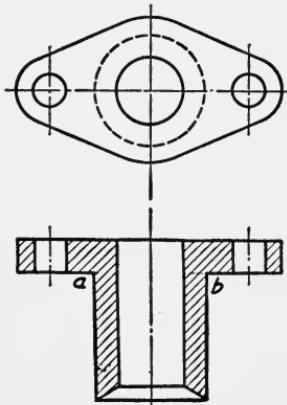


FIG. 83.

tional straight-line method, but the thread lines slant in a direction reverse to those of a right-handed outside thread. The threads which appear in the section are those on the far or rear side of the tapped hole; see Fig. 85. Fig. 84 shows the collar with the set screw in place. Fig. 85 shows the same collar with the set screw removed, and the tapped hole which receives it exposed to view.

Half-sections often show the interior construction of an object so well that many broken lines may be conveniently omitted from the other half of the view. In the view that is half-sectioned, avoid running dimensions from the sectional part to the full part; rather show them in the other view of the object, unless the part dimensioned is shown by a full line in both parts of the view. Also avoid placing dimensions, or running extension or dimension lines across the cross-hatched portion of the view, although this is sometimes necessary.

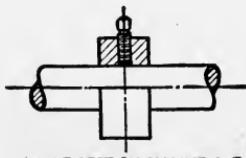


FIG. 84.

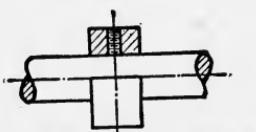


FIG. 85.

Always put the cross-hatching on *after* putting on the dimensions, so that in case it is necessary to put a dimension in the cross-hatched area, a break may be made in the cross-hatching.

It does not make any difference in which direction the cross-hatching lines slant, so long as they make an angle of 45° with the horizontal, except that on the same piece they should all slant in the same direction. You will find it most natural, however, to begin in the upper left-hand corner of the view to be cross-hatched. The spacing can be judged by the eye, the lines being about $\frac{1}{16}$ in. apart.

38. Broken Sections.—Cutting planes need not always be continuous; they are very often broken or “zigzagged” so as to show the construction of the object in different planes. Fig. 86 shows a drawing of a bearing block. The cutting plane for the half-section is passed along the lines *ABCDE* of the top view so as to show the interior construction at the oil hole and also at a bolt hole.

Note that the surface *CD* where the cut is set over is not indicated in the section view. Since the bearing block is symmetrical about its axis, the other half may be shown conveniently as a full elevation view. When a section plane follows a devious outline as in this case, it is shown in the plan by the usual center-line convention. Appropriate letters and notes should show where the cutting plane is passed, and the section view should be labelled accordingly. It is general practice to omit such notes where the cutting plane is passed along the main center line, as in Figs. 81, 82, 83, 84, and 85. Notes were used on these drawings merely for the information and direction of the student.

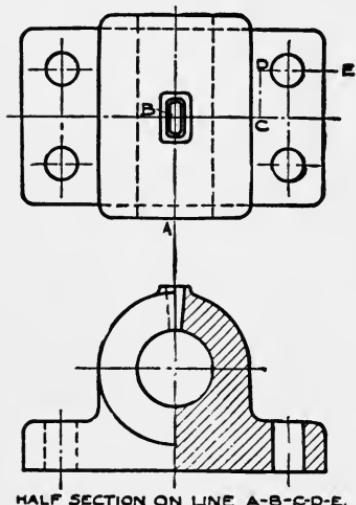


FIG. 86.

Second.—The square corners on the pattern make corresponding square corners in the sand and these corners in the sand are difficult to keep intact, thus causing the molder a lot of trouble.

Third.—The most important reason, however, for rounding the corners is that they give the casting more uniform strength, while with square corners the weakest parts of the casting are the corners.

Figure 87 shows the method of crystallization in a casting with sharp corners. As the iron hardens, the crystals seem to form in lines perpendicular to the faces, as indicated by the lines in Fig. 87. This will leave an open space, or a space of irregular crystallization at *b*; and the casting is liable to break along the

39. Fillets.—The most frequent error of the inexperienced draftsman is his habit of showing sharp corners on castings, though it is very natural that he should if he sees no reason for not doing so. In all probability such errors on the part of the draftsman would be taken care of by the pattern-maker unless he, too, were inexperienced, when trouble would be likely to occur.

There are three reasons why sharp, square corners are objectionable and why we use rounded outside corners and fillets.

First.—The rounded corner presents a more pleasing appearance.

line *a-b-c*. By rounding off the outside corner, and placing on the inside corner a fillet (which is the name applied to an inside rounded corner), we change conditions to those shown in Fig. 88 where the lines of crystallization are all perpendicular to the surfaces, and where there are no open spaces or places of irregular crystallization.

In drafting, always show rounded corners, both inside and outside, on castings which are to have those corners left in the rough, that is, not machined.

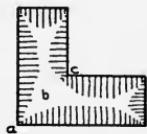


FIG. 87.

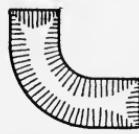


FIG. 88.

Generally a corner of $\frac{1}{8}$ -in. to $\frac{3}{8}$ -in. radius is used according to the size of the part. The radius to be used is frequently left to the judgment of the pattern-maker, in which case it need not be noted on the drawing. When larger radii are used there is generally a definite reason for the given size, and it should be specifically noted.

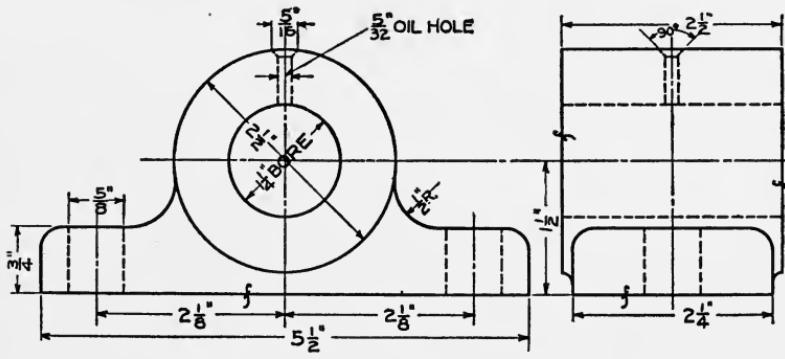


FIG. 89.

Problem 9

Fig. 89 shows the side and end views of a plain bearing block. Make a full-size pencil drawing of this block showing the views indicated in Fig. 90. Use a 9-in. \times 12-in. sheet with the 12-in. dimension vertical.

The views can be arranged to better advantage if the sheet is placed on

the board with the long dimension vertical. The 1-in. margin should be at the top. Place the top view 1 in. from the top border line, and allow $\frac{1}{4}$ in. between the views. This arrangement will allow sufficient space at the bottom of the plate for the title.

In Fig. 90 the sectional view is shown cross-hatched all over. This was done simply to show which view, and which part of the view, is to be cross-hatched. It does not mean that the whole part is to be cross-hatched as shown here. The student will need to determine for himself just where the cross-hatching should be placed. This explanation also applies to problems which are to follow.

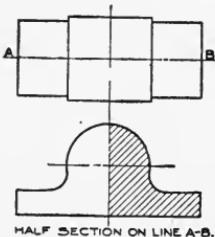
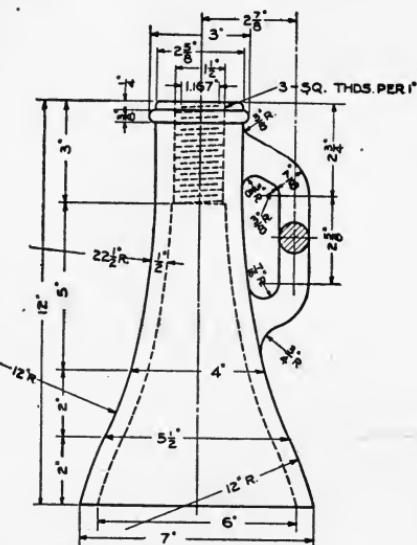


Fig. 90.



READY FOR 12 TON JACK SCREW
I-REQUIRED CAST IRON

FIG. 91.

ASSIGNMENT 10

Problem 10

Make a half-size pencil drawing of the jack-screw body shown in Fig. 91, drawing the views and half-section indicated in Fig. 92. It will be found necessary to use one of the 12-in. \times 18-in. sheets. The sheet should be placed on the board with the 18-in. dimension vertical. Draw the border

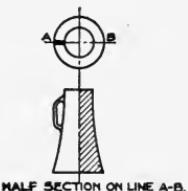


FIG. 92.



FIG. 93

lines so that the margin at the top will be 1 in. wide, and on the other three sides $\frac{1}{2}$ in. wide.

Draw a vertical center line in the middle of the sheet, and, after allowing 2 in. between views, locate the center of the top view so as to leave an equal amount of space between the views and the top and bottom border lines.

In the part of the drawing where the threads are shown in section, it will be necessary to show the thread outlines. This can be done as shown in Fig. 76, except that in this drawing the threads will slant in the opposite direction, as it is the back part of the threaded hole that is being shown here. The threads should not be drawn all the way across the hole, but only as far as the center line, since this view is a half-section. It will be necessary to lay out at least one thread on the opposite side of the hole, however, to get the proper slope for the threads. After drawing in one, the others can be drawn parallel by using both triangles.

The conventional method of representing cast steel in section is shown in Fig. 93, being two fine parallel lines close together, then a wider space, then two more lines like the first, etc.

ASSIGNMENT 11

40. Partial Sections.—When a section is needed to show the interior construction of a machine part in only one particular place, we can imagine the metal in front of that place broken away so as to leave the hidden parts exposed. This is the method

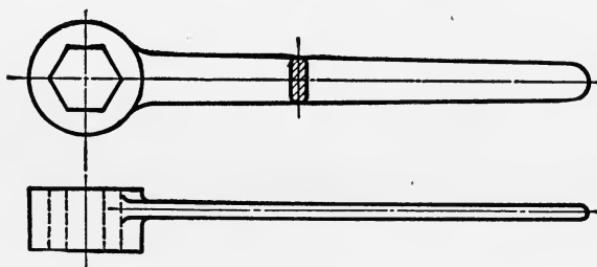


FIG. 94.

that was used to show the cap screws in Fig. 68. To do this, a wavy line is drawn free-hand around the part, and the proper cross-hatching is placed inside the broken space. This makes it appear as if the metal had been broken away roughly.

41. Revolved Sections.—The necessity of drawing an extra view of an object may frequently be avoided by the use of a revolved section. For an example of the revolved section see Fig. 94. Notice that it consists in drawing a cross-section of the handle on the plan view, thus doing away with the necessity of making a separate end view in order to show the shape of the section of the handle.

Fig. 95 shows how a piece of an object may be broken out to leave room for the revolved section. This is especially desirable in this case because the arm tapers, and consequently the lines of

the lower flange would cross the section if it were drawn on the object, as in Fig. 94 without breaking away the arm.

Fig. 96 illustrates a common method of showing sections where the sections are different at different points along a piece. The sections are drawn off the view but the lines at which they are taken are located on the drawing of the object. This method is frequently used in showing the shape of long parts such as lathe legs, connecting rods, etc.



FIG. 95

Pulleys, hand wheels, gears, and other such circular objects are usually shown by two views, one of which is a section.

Fig. 97 shows a complete conventional drawing of a six-arm pulley. It will be noticed that the section plane is passed along the vertical center line, but that the arms which would really be cut in making the section are not cross-hatched and, instead, the section is shown as if it passed just to one side of the arms. As stated in Art. 36, it is the general practice not to cross-hatch

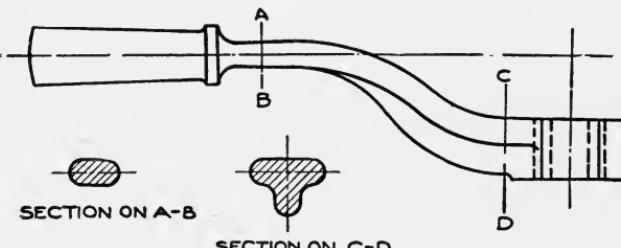


FIG. 96.

the arms of pulleys, hand wheels, etc., when cut lengthwise. Only the hub and rim should be cross-hatched. It should be noted that the inside surfaces of the rim should be shown by full object lines all the way across, as if the section plane had been passed just in front of the arms, thus showing only the rim and hub in section.

For greatest strength, the keyway should always be shown on the center line of one of the arms, and not midway between two

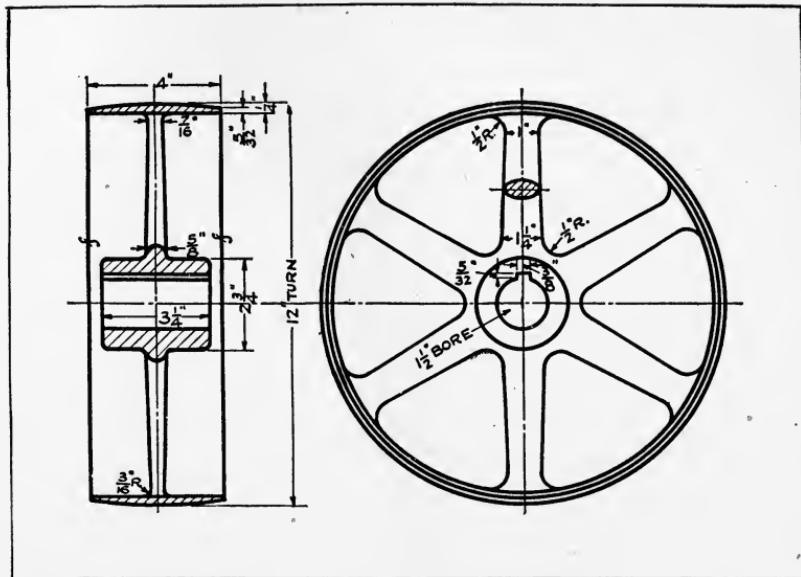
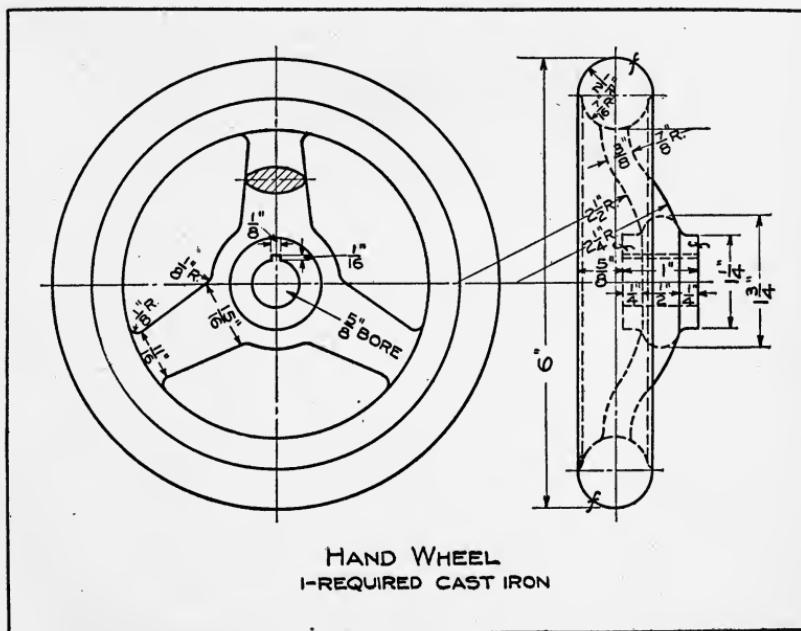


FIG. 97.



8

FIG. 98.

arms. The *face* of this pulley is 4 in. Instead of being flat or straight, it is *crowned*. Different authorities recommend that pulleys should be crowned (or have a rise of) from $1\frac{1}{8}$ in. to $\frac{3}{8}$ in. per foot of width, but $\frac{1}{8}$ in. per foot of width is a good average. The crown is for the purpose of keeping the belt on the pulley. Pulleys for use with shifting belts should be straight or flat, that is, without crowning.

Note that the diameter of the pulley is marked *TURN*. This means that enough stock must be left on the pattern so that the pulley can be turned down to the required diameter.

A revolved section on one of the arms is used to give a clear idea of its cross-section.

42. Shortened Views.—Fig. 95 illustrates a common practice in showing long slender objects, of breaking and leaving out

part of the length in order that the piece may be shown on the paper without using too small a scale. The long arm in Fig. 95 is broken and the two end pieces placed closer together than they would actually be if the full arm had been drawn. This permits the use of a larger scale on the parts shown. The full length of the arm should, of course, be given in dimensioning.

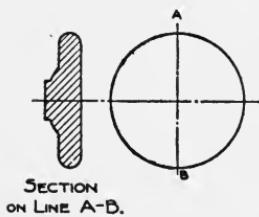


FIG. 99.

Problem 11

Make a full-size pencil drawing of the hand wheel shown in Fig. 98 making the views shown in Fig. 99. Use a 9-in. \times 12-in. sheet for this plate.

By referring to Fig. 98 you will note that in the front view there are three spokes, while the side view is drawn as if there were two spokes, and these directly opposite each other. The left-hand view is depended upon to show the number and arrangement of the spokes. If we attempted to show the spokes in the side view as they would actually appear when the hand wheel is in this position, the two lower spokes would appear shortened. It would be more difficult to show the spokes in this view as they really are, and would make the drawing less easy to read.

In making the section of the hand wheel, the student should show the spokes as if they stood vertically, in the same manner as shown in Fig. 98. As explained in Arts. 36 and 41, the spokes should not be cross-hatched. The rim and the hub only should be cross-hatched.

A revolved section of one of the spokes should be shown on the front view.

CHAPTER IV

TECHNICAL SKETCHING

ASSIGNMENT 12

43. Use of Sketching.—The ability to make neat, clear, comprehensive sketches of machine parts is one of the most valuable assets a draftsman, designer, or engineer can possess. Quite frequently it happens that a repair part, for which there may be no regular drawing, is required. The draftsman takes a pad of paper, a pencil, a rule, inside and outside calipers, a machinist's square, and, in some cases, a protractor, and goes direct to the machine in question, where he makes a complete sketch of the broken part. This he dimensions fully, adding any notes that may be required. The sketch is not made to any scale, but is laid out by eye or by some rough measurement to secure the right proportions. This sketch is rushed through the shop with all possible haste, and the repair part is often completed and installed in the machine in less time than it would take to make and trace a mechanical drawing of the part required. If it is desired to have a permanent drawing of the part, a regular mechanical drawing is made from the sketch and filed away in the usual manner.

The designer or engineer uses the sketch as a means of recording his ideas at once, before he may forget them. The draftsman keeps a sketchbook, the pages of which are made of cross-section paper; that is, paper ruled in light horizontal and vertical lines spaced $\frac{1}{8}$ in. to $\frac{1}{4}$ in. apart. With the aid of these lines he is able to make correctly proportioned sketches without the use of the scale. Such a book, when filled with sketches, is filed away so as to be of use at some future time.

44. Suggestions for Sketching.—There are many points to consider in measuring an object and making a drawing of it, but a good mechanic is often better endowed with common sense in this respect than is a regular draftsman, because he knows better the operations used in making a piece and can see what dimensions are most important. A few *don'ts* by way of caution

will point out some of the most common errors in this sort of work. These are taken from "Don'ts for Draftsmen and Machinists," published by "Machinery."

- Don't forget fillets.
- Don't repeat dimensions.
- Don't use fancy lettering.
- Don't put unnecessary finish on parts.
- Don't forget clearance for moving parts.
- Don't ever forget to put the scale on a drawing.
- Don't fail to sign all drawings which you make.
- Don't give dimensions in 32ds when 8ths are close enough.
- Don't put important dimensions where they may be overlooked.
- Don't omit minor details; it causes endless confusion and delay.
- Don't fail to use stock sizes of drills, reamers, etc., when possible.
- Don't make three or four different views of a piece when one or two views will do as well.
- Don't forget center lines. A circle without its center lines looks like a bald-headed man.
- Don't put a lot of cored work on a "one-casting-only" job. A little extra metal is cheaper.
- Don't imagine rough castings come just like the drawing; they vary and you must allow for it.
- Don't give the same dimension twice, for it is liable to lead to errors when this dimension is changed.
- Don't leave some dimensions to be gotten by adding a lot of other dimensions together or by subtracting them.
- Don't forget that the molder despises sharp square corners—internal ones more than the external ones.
- Don't, when lines are close together, make arrows so that the workmen cannot tell which line they go to.
- Don't put all dimensions on, then all arrowheads; you are sure to miss some of the latter by this method.
- The object of this assignment and of the one that follows will be to train the student's hand in the making of sketches of machine parts. A few exercises in the making of straight horizontal and vertical lines will be taken up before attempting to make any sketches of machine parts. For this purpose a 2H pencil is best fitted.

To sketch horizontal lines, hold the pencil about 2 in. from the point, as shown in Fig. 100. Swing the forearm from the elbow, making the line by a series of connected dashes. For vertical lines hold the pencil as shown in Fig. 101. When the views are completed go over the lines to make them heavier. After a little



FIG. 100.

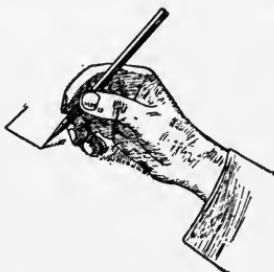


FIG. 101.

practice the student will find that it is much easier to sketch straight lines by the use of short connected dashes than by attempting to make one continuous line.

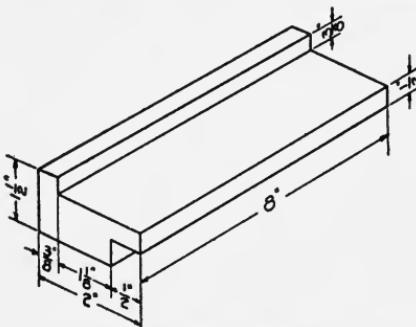
Problem 12

In Fig. 102 is shown a picture, in one view, of a movable jaw for a planer chuck. The student should decide for himself what views are necessary to properly show this object, and should make such a sketch, showing all necessary dimensions and notes. As far as possible, make the views of correct proportions. Use a 9-in. \times 12-in. sheet of drawing paper, but do all the work free-hand, and lay out the drawing by eye, and do not use a scale on the drawing.

ASSIGNMENT 13

45. Sketching on Plain Paper.—Free-hand sketching is somewhat difficult to the beginner because he must use his judgment and sense of proportion, while in mechanical drawing the use of the scale does away with this necessity.

As mentioned in the last assignment, cross-section paper is often used in free-hand sketching, as it not only makes vertical



MOVABLE JAW FOR PLANER CHUCK
2-REQUIRED CAST IRON FINISHED

FIG. 102.

and horizontal lines easy to draw, but it also makes proportioning easy.

Plain paper, however, is more frequently used because of the fact that cross-section paper is less common and less easily obtainable. It is desirable, therefore, to adopt some means as an aid to the correct proportioning of views on plain paper. The

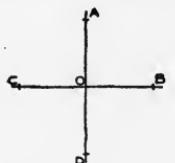


FIG. 103.

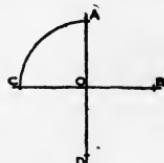


FIG. 104.

most common aid is the pencil itself. The approximate proportions of the object are obtained by measuring all dimensions in pencil lengths and fractions of such lengths. The outlines of the drawing are then blocked out to some desirable size on the sheet and the overall dimensions are divided up in the same number of equal parts and fractions of parts as there were pencil

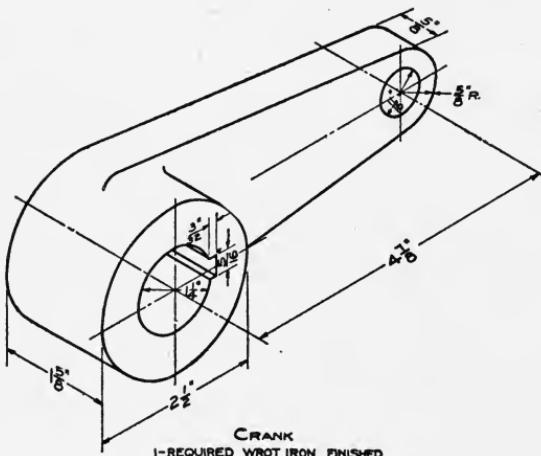


FIG. 105.

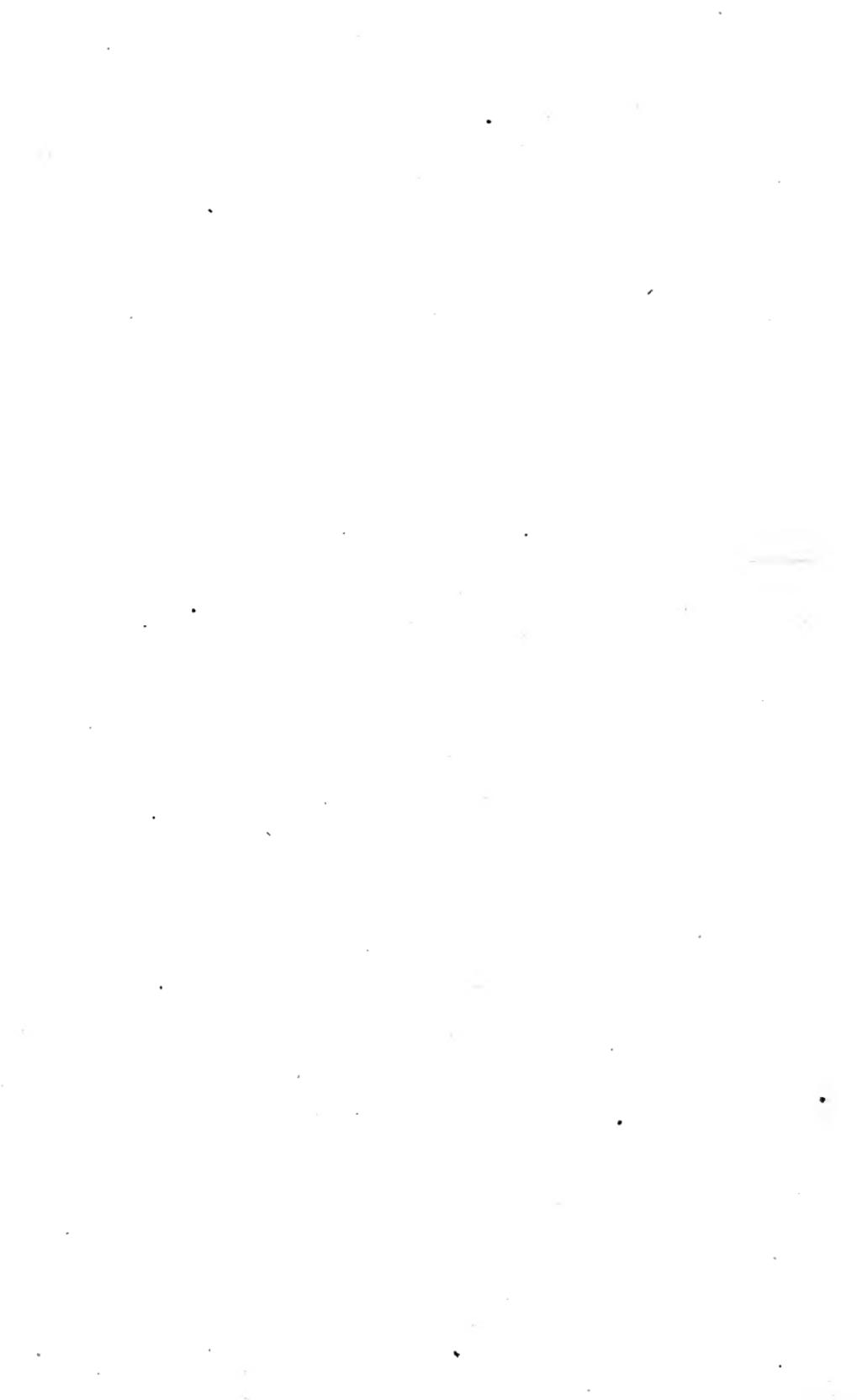
lengths on the actual object. One of these divisions on the outlines of the drawing is then marked off on the pencil and becomes the standard unit of proportion for all parts of the drawing. In drawing circles it will be found that this method is very helpful to beginners. It proves its value on circles and arcs of circles much more than on straight lines.

In sketching from pictures it is only necessary to assume some convenient length as representing an inch on the drawing, to mark it off on the pencil, and to apply it as many times as necessary to give the approximate required dimensions. By this means it is a simple matter to obtain a drawing that is approximately half, double, or, in fact, any other proportion to the size of the actual object.

46. Sketching Circles.—To sketch a circle, draw the horizontal and vertical center lines first. Next, from the intersection of the two center lines, lay off the radius of the circle on each of the four lines, as OA , OB , etc. in Fig. 103. Now connect A and C with a smooth curve, as shown in Fig. 104. Sketch this curve in lightly, at first, after the manner of sketching straight lines. After the circle is completed satisfactorily, make it heavier.

Problem 13

Fig. 105 shows a fully dimensioned picture of a crank. Make a free-hand sketch showing two views of this object. Dimension fully, and add all necessary notes. Use a 9-in. \times 12-in. sheet with the 12-in. dimension vertical.



CHAPTER V

TRACING

ASSIGNMENT 14

47. Use of Tracings.—In all up-to-date drafting offices the pencil drawings are never allowed to be taken out of the office, but are traced on transparent cloth, and from this blue prints are made. In the larger drafting offices the work is usually done by two different departments; namely, the drawing department and the tracing department. In the former, all pencil drawings are made. After being carefully checked and approved, they are taken to the tracing department to be traced on cloth. The tracings are likewise checked and approved before prints are made for the shop.

While tracing is the first step of an apprentice draftsman in his profession, the student in mechanical drawing will find that considerable care, practice, and skill are required to make a satisfactory tracing.

Tracings are used for the purpose of making duplicate copies of drawings, usually upon blue print paper, and are usually made upon a prepared linen cloth called tracing cloth, although any thin paper that is transparent may be used. The cloth should be used for all permanent drawings as it is tough and will outlast any kind of paper that may be used.

Tracing cloth is a fine-thread fabric which has been sized and transparentized with a starch preparation. The smooth, or glossy, side was originally intended to be used for the drawing as the ink will flow freely on this side without any special preparation. It has the disadvantage, however, of reflecting light and causing eye-strain. Also, the dull side is preferred by most draftsmen because it takes a pencil mark. Tracing cloth, in rolls, has a red thread along both edges which protects it in shipment. These threads should always be torn off before using the cloth so that it will lie flat on the drawing board. The cloth should be stretched over the drawing and secured to the board by means of thumb tacks.

48. Aids to Tracing.—Tracing cloth, as placed upon the market, contains an oily preservative which, unless removed, causes "wire-drawing" of the ink lines, that is, the ink does not flow freely and the lines are very irregular. To overcome this effect, some gritty substance such as chalk dust, fuller's earth, magnesia, talcum powder, or powdered soapstone should be rubbed over the surface of the cloth, and the surplus wiped off with a cloth. The same result may be secured by wiping the surface with a cloth dampened with gasoline. This method has the advantage that it leaves no grit to catch in the pen and thus smear the ink.

Since tracing cloth is much more expensive than paper, it should be handled carefully. It is very sensitive to atmospheric

changes and may expand over night so as to require restretching. If the complete tracing cannot be finished during the day, one or more views should be finished, and no view left with only part of its lines traced. Water will ruin a tracing, and moist hands or arms should not be allowed to come into contact with the cloth. Unfinished tracings should be covered when not in use.

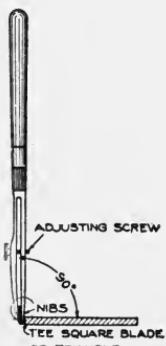


FIG. 106.

Before attempting to trace a drawing the student should practice with his ruling and lettering pens on a separate piece of cloth. Use this sheet of cloth for setting the ruling pens for various widths of lines (see Fig. 42, Assignment 2).

Test both lettering and ruling pens before attempting to put any ink on the drawing. Do not dip either lettering or ruling pens into the ink. Use the quill dropper in the stopper of the bottle. The ink should lie between the nibs of the ruling pens, as shown in Fig. 106, and on the under side of the lettering pens. Do not use too much ink on the latter as it is liable to drop onto the tracing.

49. Erasures.—The student should practice the erasure and subsequent "piecing-in" of ink lines on tracing cloth. Never make any erasures with a knife or other sharp instrument, as the sharp edge cuts into the strands of the cloth and causes any lines which are subsequently drawn upon the erased part to smear and spread. If an erasure is necessary, first use the ink eraser gently and then the pencil eraser so as to smooth the cloth again. Sometimes it is desirable to rub the cloth with the end of the handle of a pocketknife or other blunt instrument in order to

work the threads of the linen together. In any event, soapstone should be rubbed into the spot and gently brushed away before inking upon it again. This may be done merely by rubbing the soapstone stick itself upon the cloth. The student will find it to his advantage to slide his triangle under the part to be erased as it gives a smooth hard surface to erase upon.

When piecing-in a line which has been erased, the pen should be set so that it will make a line slightly narrower than the line which is being pieced-in, as there is a tendency for the ink to spread at the two junction points, and the junction points will be less apparent in the finished tracing, if the pen is given the narrower setting.

50. Removal of Blots.—Be careful to let the ink lines dry before moving the triangles or the T-square over them; otherwise they will be apt to blur. If a blot should occur on the tracing from the pen being too full, or in any other manner, or if an error be made in drawing a line, smear it with the thumb or with a blotter before it has a chance to soak in. *After it is thoroughly dry* make the necessary erasure as before directed. This process may spoil some of the work already done, but if the ink is allowed to soak in, it will be more difficult to make the erasure.

In erasing a line or letter, great care must be exercised or the surrounding work will also be erased. To avoid this, an erasing shield, as shown in Fig. 107, is used. It is made of brass or celluloid, and is provided with small slots as shown. The erasing is done through the slots and the shield moved about until the desired lines have been erased.

51. Order of Procedure in Tracing.—To get the best results, drawings should be traced in the following order, using particular care to do all the work requiring a certain weight of line before changing the setting of the pen (see Fig. 42, Assignment 2).

1. All center lines.
2. Small circles and fillets.
3. Large circles.
4. Straight lines.
5. Extension and dimension lines.

Draw top and bottom pencil guide lines for lettering.

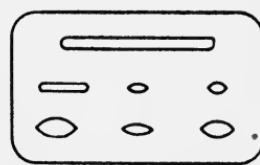


FIG. 107.

When the tracing is completed, wipe the surface with a cloth dampened with gasoline. This will remove all dirt and pencil lines.

Problem 14A

Make a complete tracing of the pencil drawing which you made for Problem 1 of this course.

Be careful to differentiate between the various weights of lines, for this is one point that distinguishes a good piece of work from a poor one. Follow carefully the instructions given in Art. 51.

Problem 14B

Make a complete tracing of the pencil drawing which you made for Problem 2 of this course.

Follow carefully the instructions given in Art. 51.

ASSIGNMENT 15

52. Suggestions on Lines.—Center lines, extension lines, and dimension lines should all be light lines of uniform weight (see Fig. 42). The center lines should all be drawn with one setting of the pen. The main center lines of an object should project about $\frac{1}{2}$ in. beyond the drawing of the object, while secondary center lines should project about $\frac{1}{4}$ in. beyond the lines which they center.

Extension and dimension lines should be drawn with the same weight of line that was used in drawing the center lines. The extension lines should fail to touch the object lines by $\frac{1}{8}$ in. and should extend about $\frac{1}{8}$ in. beyond their dimension lines. The extension and dimension lines should all be drawn with one setting of the pen. Always arrange dimensions of circles symmetrically between the center lines as shown in Fig. 43. Never place dimension lines of circles on the center lines. If the finish of a cylindrical hole is shown by a note carried outside of the drawing by means of an arrow, the arrow should extend clearly within the limits of the circle, point toward the center, but should not extend clear to the center (notice the $\frac{5}{8}$ -in. *drill* in Fig. 47).

53. Handling the Pens.—Before starting to trace any set of lines, the pens should be tried on an extra piece of tracing cloth, in order to be sure that they are set to produce lines of the proper width before applying them to the tracing. Do not hesitate to wipe the pens freely at all times, as the ink dries quite readily

and frequent wiping of the pens is necessary. If the ink dries in the pen temporarily, its flow may sometimes be readily renewed by trying it on an extra piece of tracing cloth, on the soft wood of the drawing board, on the fingers, or on the finger nails. Should any attempt to start the flow of the ink prove unsuccessful, the pen should be wiped clean and refilled.

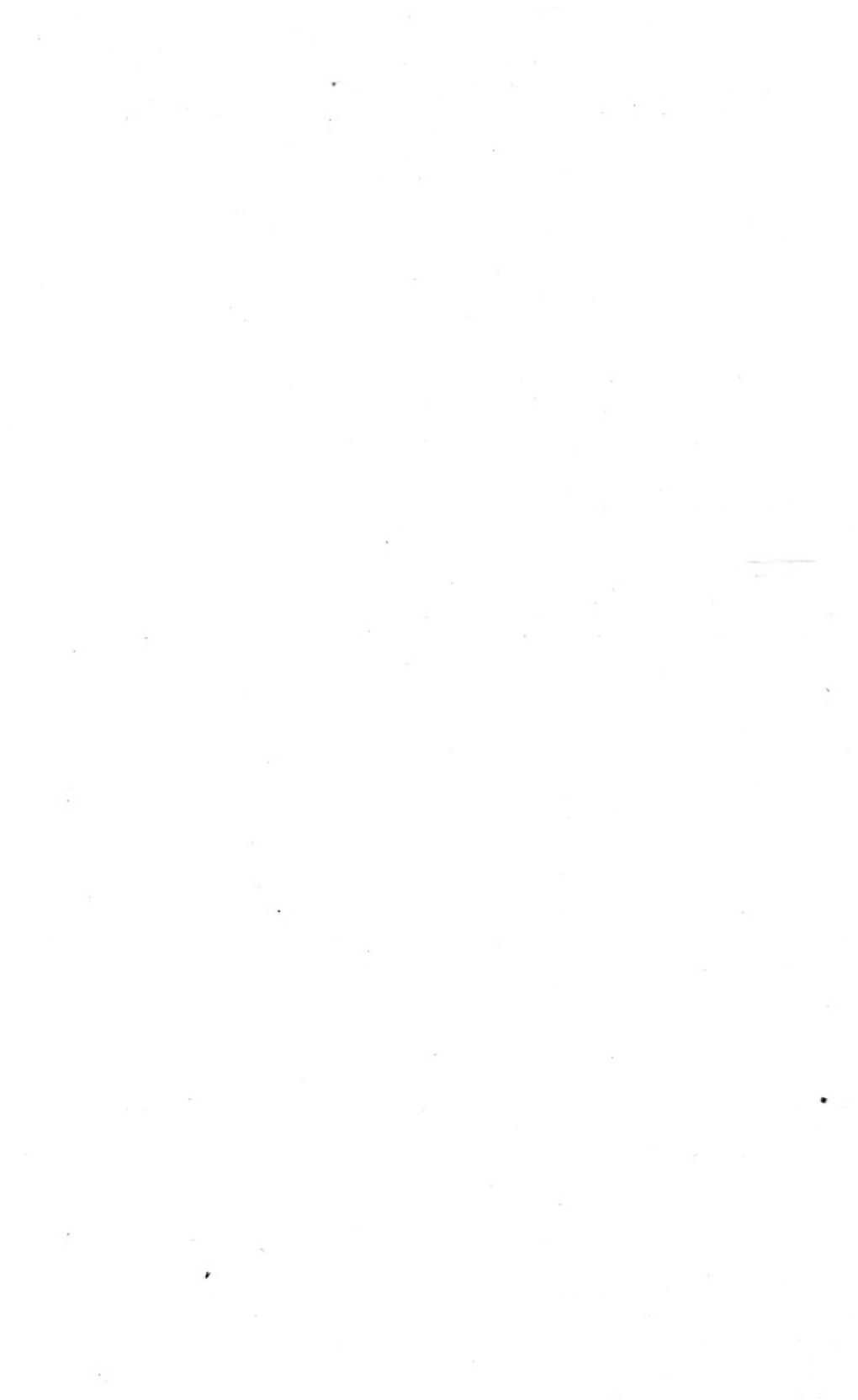
Pens should always be cleaned before putting away, as the ink will corrode the steel.

Problem 15A

Make a complete tracing of the pencil drawing which you made for Problem 10 of this course.

Problem 15B

Make a complete tracing of the pencil drawing which you made for Problem 11 of this course.



CHAPTER VI

ASSEMBLY AND DETAIL DRAWINGS

ASSIGNMENT 16

54. Assembly and Detail Sheets.—Every machine or mechanism containing several parts should be represented by both assembly and detail drawings. The *assembly* shows how the various parts are related to each other and how they are put together; the *detail drawings* are used by the mechanic in making the separate parts.

If the mechanism involves a large number of parts, there will be a single assembly drawing and one or more sheets of details. There may be a separate detail drawing of each part, or several details may be shown on one sheet. If a mechanism contains only a few parts, the assembly and the details may be shown on a single sheet. In this case, the usual practice is to place the assembly drawing on the upper left-hand corner of the plate, the rest of the plate being given over to the drawings of the details, as in Fig. 108. The drawing of Fig. 108 shows the assembly at the left. The front view is shown as a half-section, so that both the inside and outside relations of the parts are seen. All the principal details of the stuffing box are shown at the right. The nuts are not drawn in detail because they are standard hexagon nuts.

In making detail sheets, the details are sometimes drawn on the plates in the logical order in which they occur in the machine; that is, adjacent parts in the machine are drawn adjacent to each other on the detail sheets. Sometimes the details of units of the machine which are to be made, and perhaps assembled, in one part of the shop, are grouped together on the detail sheets. In other cases, it may be convenient to group together the details of similar parts which are to be made by the same mechanic or department. For instance, we may place together in one group the details of all shafts required; in another group we may have all the gears; in another group all the bolts, screws, and other parts to be made on screw machines. The choice of

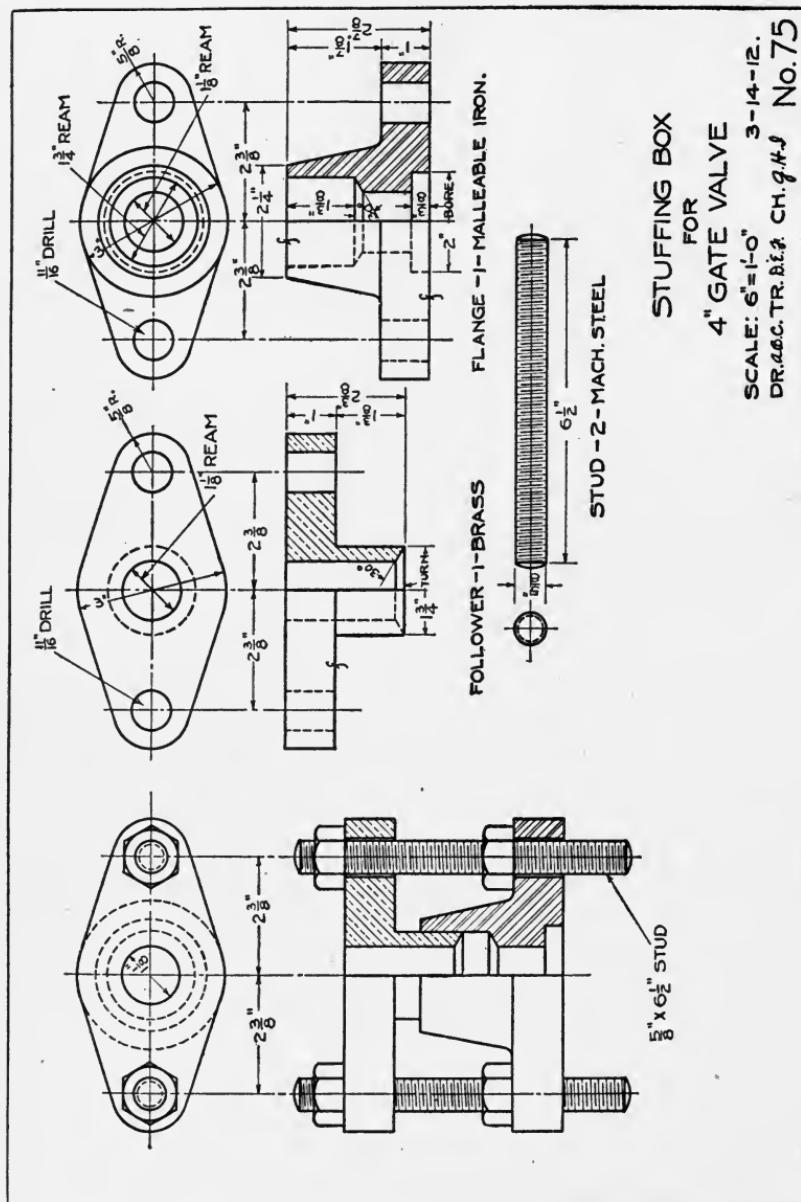


Fig. 108.

any such methods as above noted will be determined largely by the local conditions governing the manufacture of the machine and by the number of parts to be shown.

It is generally necessary to make mechanical drawings to some convenient scale. The space allotted to each detail should bear some reasonable proportion to the space allotted to other details. In other words, a comparatively small and insignificant part should not be drawn to a large scale while a larger and much more important part is drawn to a much reduced scale. If, however, a certain small part is highly important and complicated in design, it may be advisable to draw it to a large scale in order to show it clearly and to emphasize the fact that it should be accurately made. *Always strive at balance, so that the space given to each detail will be proportional to its importance and size.*

The detail drawing of each part should be complete and give all necessary information. Beneath each detail there should appear a title or "legend" giving the name of the part, the number required for one machine, the material of which it is to be made, whatever finish, if any, is required, and the scale, if different scales are used for the details. As a general rule the same scale should be used throughout. No title or legend is necessary beneath the assembly drawing, except possibly the word *Assembly*.

The title for the whole plate is usually placed in the lower right-hand corner. If the plate contains both assembly and details, the title for the plate may appear somewhat as follows:

STUFFING BOX
FOR
4" GATE VALVE

If the plate contains the assembly drawing only, the title of the plate will appear thus:

STUFFING BOX
FOR
4" GATE VALVE

ASSEMBLY DRAWING

If the plate contains only the drawings of details, the title of the plate will appear thus:

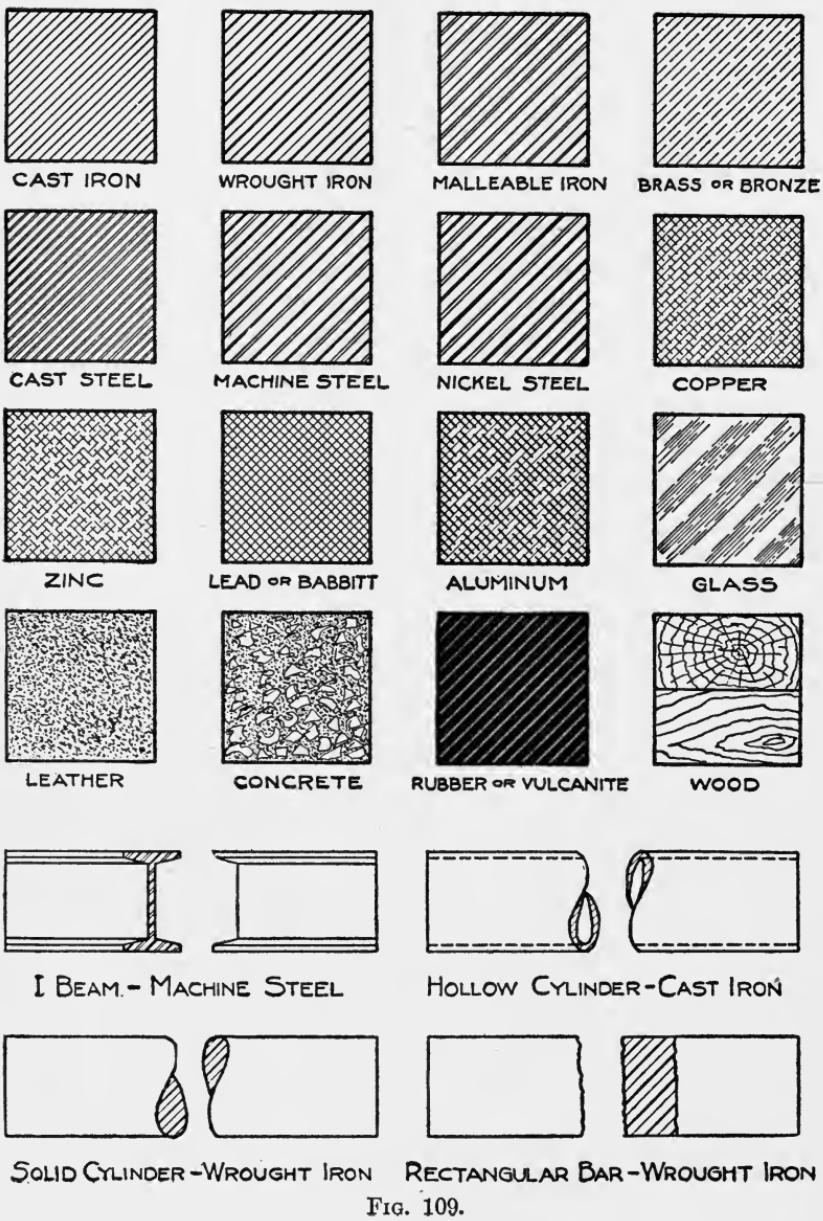


FIG. 109.

DETAILS OF STUFFING BOX
FOR
4" GATE VALVE

There should also appear: the scale, the date, the filing number, and the names of the various draftsmen involved in making the drawing.

In many large offices the various details of a machine are drawn on separate sheets, one detail to each sheet. The assembly drawing is placed on one sheet by itself and a separate bill of material is placed on another sheet. The reason for drawing the various details separately is that many of these details might be used for other machines as well as for the machine for which they were originally intended. In this way the duplication of drawings is avoided.

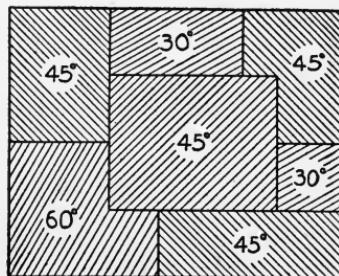


FIG. 110.

55. Conventional Forms for Cross-hatching.—In most assembly drawings, sections are used extensively to show how the various parts fit together. Since the various parts of a machine are frequently made of different materials, it is quite customary to section the various materials differently to distinguish between them. Fig. 109 shows the most common forms for cross-hatching 16 different materials; also the conventional forms for representing breaks.

In Fig. 108 it will be noted that the cross-hatching of one part slants in the opposite direction to that of the other part, and that the cross-hatching on any one part is always in the same direction. This is the universal practice and should be rigidly followed. It sometimes happens, however, that three or more parts are in direct contact with each other. If the parts are of different materials it will not matter if the cross-hatching of

adjacent parts slants in the same direction; but if all of the parts are of the same material the parts can be distinguished by using 45° , 30° , and 60° angles for the cross-hatching as in Fig. 110.

Problem 16

Fig. 111 shows complete details of a $2\frac{1}{2}$ -in. step bearing. This is the lower end housing for a vertical shaft, both to give a suitable bearing, and to maintain the position of the shaft.

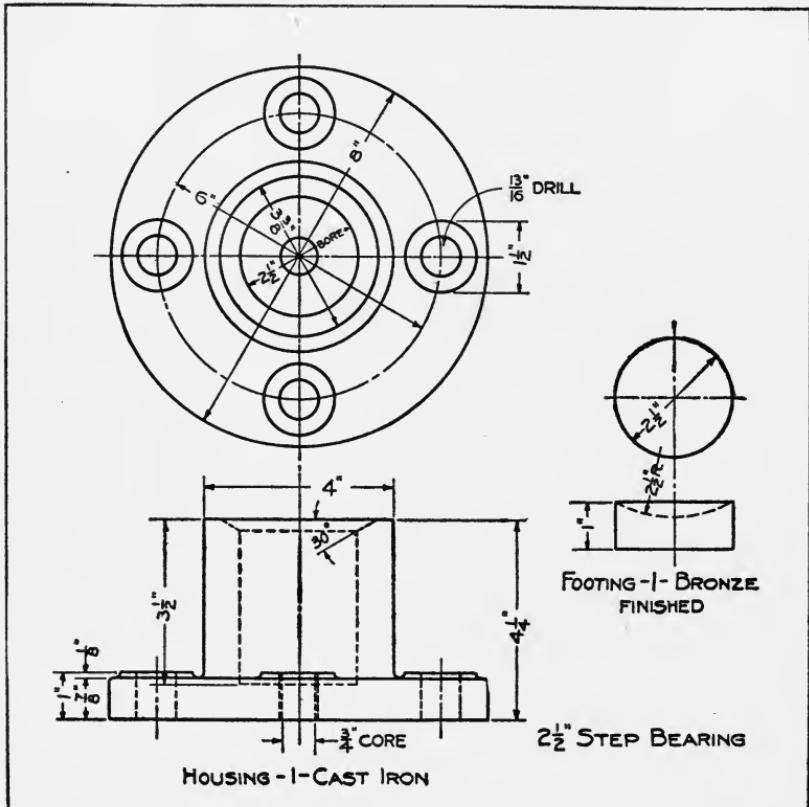


FIG. 111.

Cast iron is not suitable for a bearing; hence it is not permissible to let the shaft rest on cast iron. A piece of bronze bearing metal is fitted into the cast-iron housing. This bronze footing is cupped on the upper side to fit a 5-in. sphere ($2\frac{1}{2}$ -in. R). The end of the shaft is turned to a segment of a 5-in. sphere; thus the shaft end and the footing form a ball and socket, which keeps the shaft centered in the step. The $\frac{3}{4}$ -in. hole in the base is

provided for the insertion of a bar to drive out the footing when it is to be replaced.

Draw the views and section indicated roughly in Fig. 112, using the full-size scale. For this plate use a 9-in. \times 12-in. sheet with the 12-in. dimension vertical. When the two parts are assembled, the footing should rest at the bottom of the $2\frac{1}{2}$ -in. hole in the housing. The cupped surface of the footing should be uppermost.

Do not dimension assembly drawings in detail but give only the main dimensions, showing the relations of the parts to each other, and the main dimensions of each part.

ASSIGNMENT 17

Problem 17

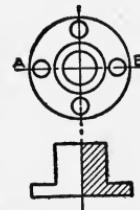
In Fig. 113 are given the details of a follow rest for a 12-in. lathe. Make a full-size pencil drawing showing the various pieces assembled as in Fig. 114. Use a 12-in. \times 18-in. sheet.

A follow rest is used on a lathe when turning long slender bars that would otherwise spring away from the tool. Where such a bar is to be turned, the follow rest is bolted to the carriage of the lathe and the guide is adjusted by means of the two set screws so that the notch bears on the top and back of the bar. This holds the piece rigidly against the tool, and, since the follow rest is attached to the carriage, it moves with the tool and follows it throughout the cut.

In making the drawing, place the guide so that the two faces of the notch are $\frac{1}{16}$ in. from the center lines of the yoke in the side view. This is the position for turning a piece $\frac{5}{8}$ in. in diameter, since the intersection of these two center lines is in line between the lathe centers.

The title of the drawing should contain the words *FOLLOW REST FOR 12" LATHE*, in addition to the usual information regarding scale, date, etc.

When you have completed the pencil drawing, make a tracing of it.



HALF SECTION ON LINE A-B.

FIG. 112.

ASSIGNMENT 18

Problem 18

Make a quarter-size assembly of the 12-ton jack screw, the details of which have already been drawn in Problems 8 and 10. See Figs. 77 and 91 for the details. Make a half-section elevation and a top view as shown in Fig. 115. Use a 9-in. \times 12-in. sheet with the 12-in. dimension vertical. Assemble the parts so that the total height of the jack is about 16 in. It will be noticed in assembling the cap and the screw that the latter would project $\frac{1}{16}$ in. through the cap. This extra length is provided so that the end of the screw may be riveted over to prevent the cap from coming off, and yet allow it to turn on the screw. In the assembly drawing, this should

be shown riveted over, and attention should be called to it by an arrow and the word *RIVET*.

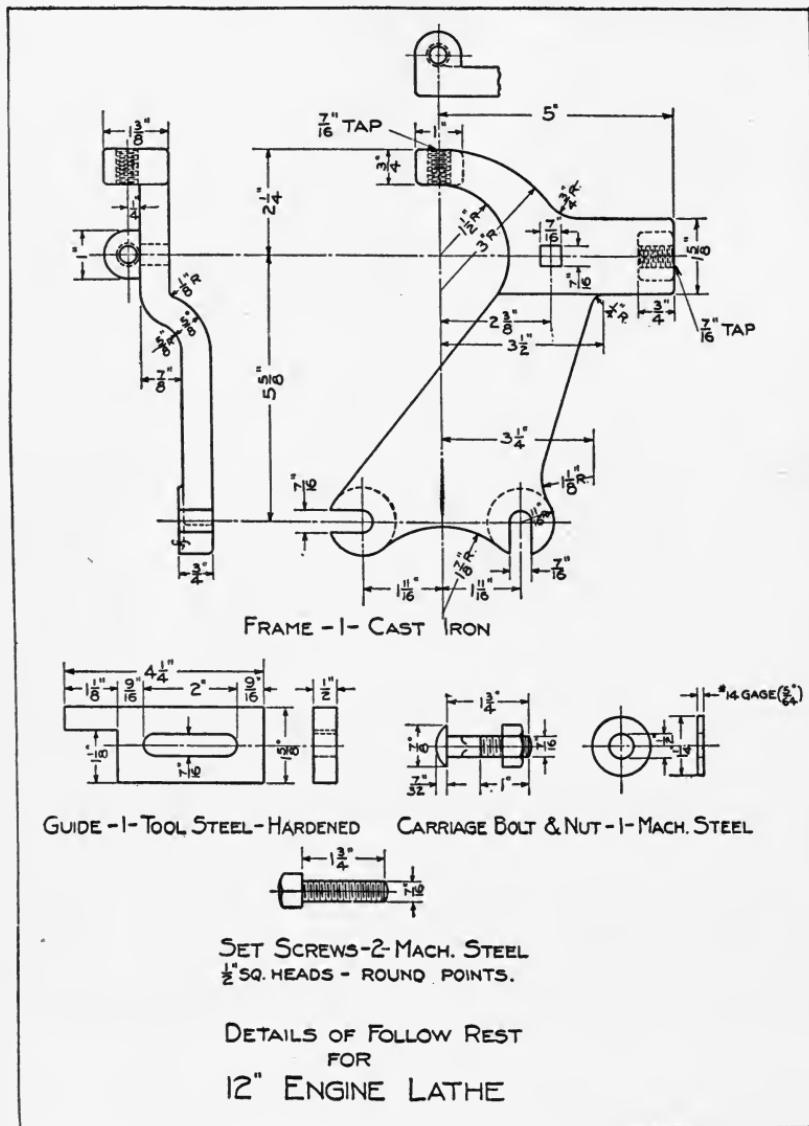


FIG. 113.

As in the preceding problem, make a complete pencil drawing of the jack and then trace it.

ASSIGNMENT 19

56. Drafting-room Procedure.—When the design of a machine is first taken up in a drafting office, the chief engineer or a senior draftsman first makes a pencil-sketch assembly. He endeavors to provide for all clearances and to proportion the parts correctly. When a satisfactory sketch has been obtained, it is turned over to a competent draftsman to work up into a finished drawing. This finished assembly is often the result of careful and frequent consultation with the various other draftsmen and engineers, so as to have all the good ideas possible incorporated into the design.

The draftsman who makes the assembly drawing decides what materials or metals it will be advisable to use in the several parts, what their treatment shall be, what proportions they shall have

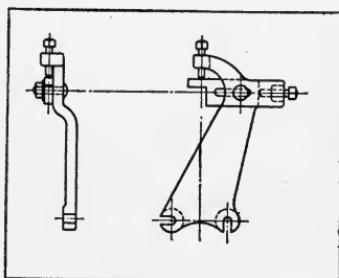


FIG. 114.

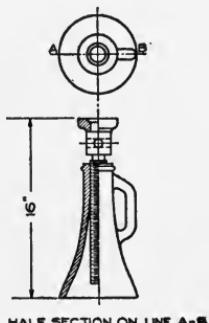


FIG. 115.

in order to give sufficient strength, etc. His drawing should show all general and vital dimensions and should be finished in such a manner that it may be placed in the hands of a junior draftsman or detailer to detail the various parts. Before going to the detailer, however, the assembly drawing should be submitted to the chief draftsman and chief engineer for their approval.

Under the supervision of the man who made the general assembly, the detailer then makes complete detail drawings of each piece of the machine. These, in similar manner, should also be submitted to the chief draftsman and chief engineer.

In a large, well-regulated office, all these pencil drawings would then be turned over to the "tracer" who would trace them on tracing cloth. These tracings should also be approved by the

chief draftsman and chief engineer. In smaller offices all these operations might be performed by one man.

The tracings are next properly indexed for filing away in the vaults. Thereafter, they may be issued on a check order system.

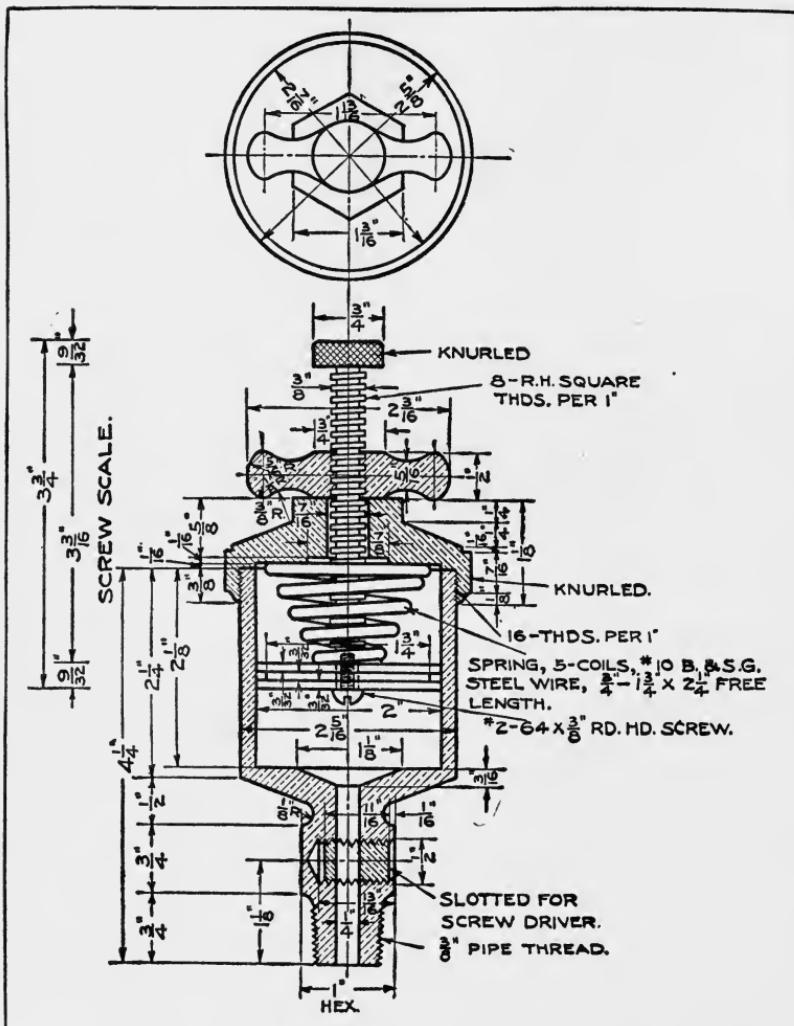


FIG. 116.

whenever it is desired to have blue prints made from them. Whenever radical changes are made in the construction of a machine, the old tracings are marked "obsolete" or "superseded," and

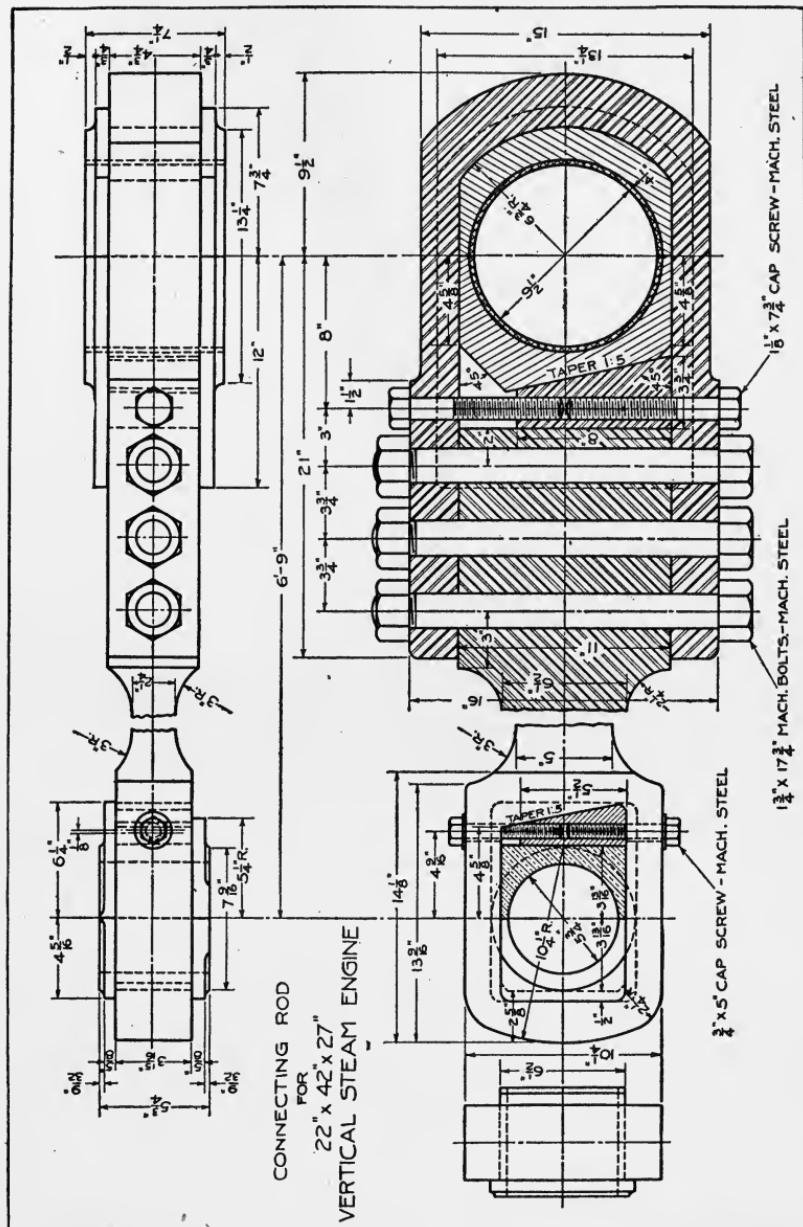


Fig. 117.

are replaced in the current files by tracings of the new designs. If only one or two dimensions are to be altered, the old dimensions may be crossed out (not erased) and the new dimensions placed above or below the old ones.

Blue prints are made on paper known as blue-print paper, which is sensitive to light. The tracing is placed over a sheet of blue-print paper in a printing frame, and then exposed to a strong light such as daylight or an electric light. This makes an impression on the blue print like the drawing on the tracing. It usually takes a minute or so to make the print in a fairly good light. The blue print is then removed and "fixed" in a water bath for a few minutes so that it will be permanent. The lines

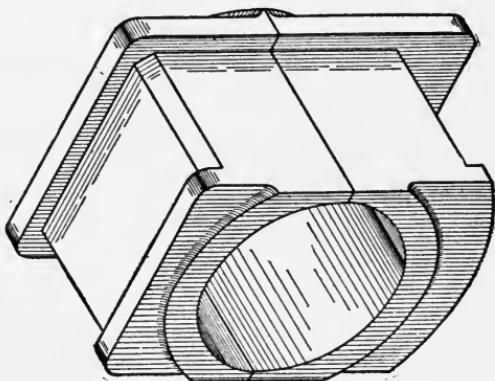


FIG. 118.

of the drawing then appear as white lines on a blue background. When blue prints are subjected to a great deal of hard usage in the shops it is well to mount them on some stiff cardboard or other firm backing and then to shellac or varnish the surface so as to protect them.

Problem 19

Fig. 116 shows a completely dimensioned assembly of an automatic grease cup. Make complete full-size pencil drawings of the various details on a 12-in. \times 18-in. sheet, placed horizontally on the drawing board. The details must be arranged on the sheet so they will not be crowded.

Put the title of each part under the drawing of it, together with the number required and the material, for example:

CAP-1-BRASS

In the plate title in the lower right-hand corner put

**DETAILS OF
AUTOMATIC GREASE CUP**

together with the scale, date, etc.

A tracing should be made after the pencil drawing has been checked by the instructor. The tracing should also be submitted to the instructor for his approval.

ASSIGNMENT 20

Problem 20

Fig. 117 shows a completely dimensioned assembly of a connecting rod for a 22-in. \times 42-in. \times 27-in. engine. Draw fully dimensioned details of all parts, using as many 12-in. \times 18-in. sheets as are necessary. The stu-

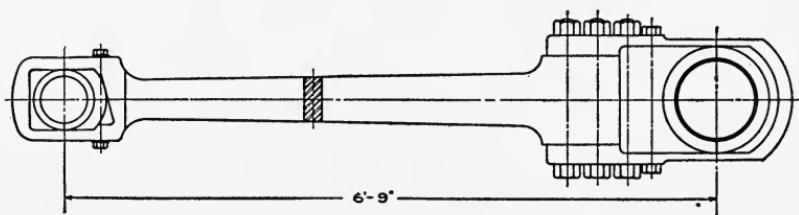


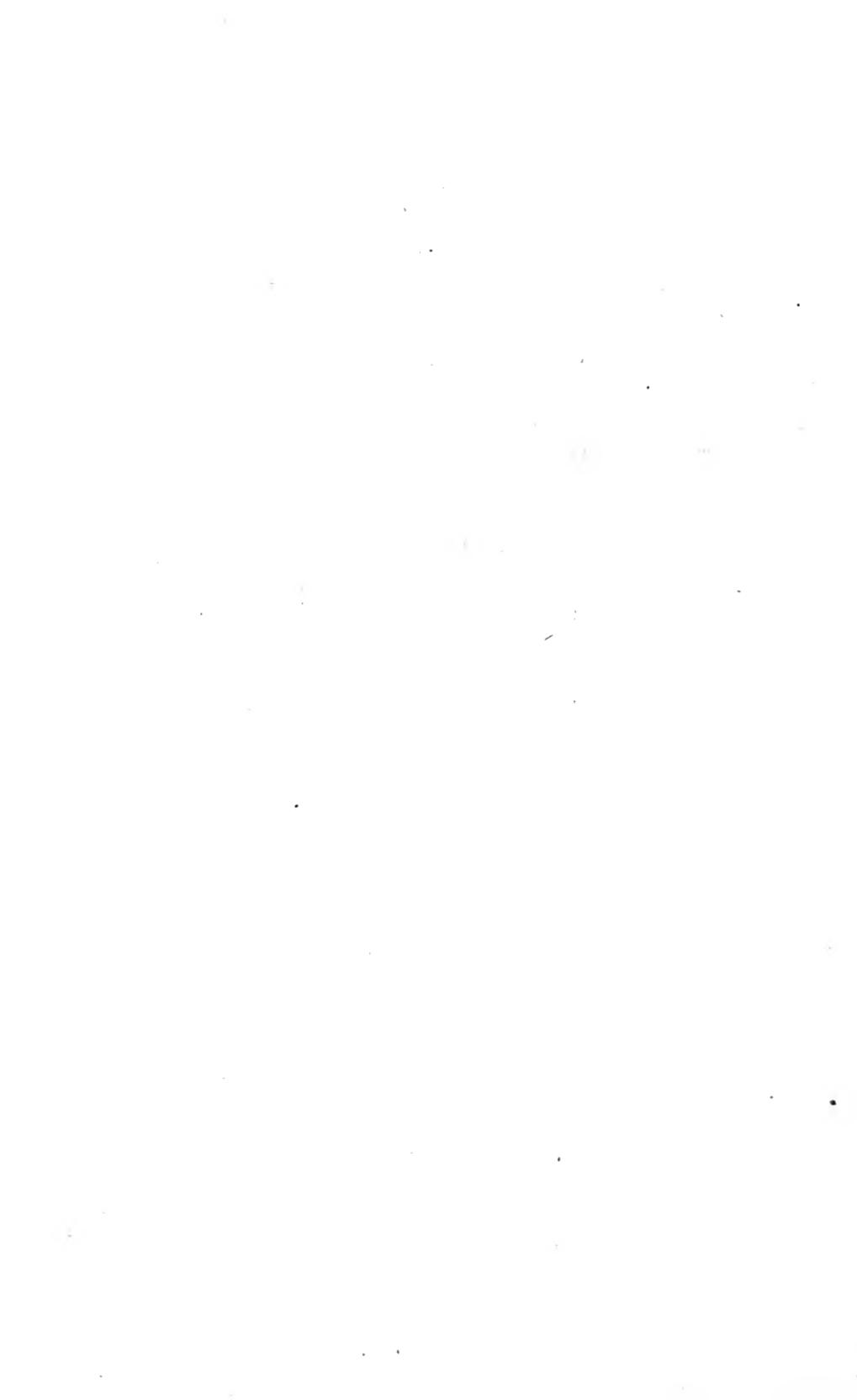
FIG. 119

dent should decide what scale, or scales, to use for these details. Always use the largest scale that the working space will permit. If more than one scale is used on the same sheet, the scale of each detail should be noted in its legend, as stated in Art. 54.

It will be necessary to break out portions of the rod in order to get the complete view on the sheet. In doing this, however, be sure to omit no part of the rod which is necessary for complete dimensioning.

Fig. 118 shows a picture of the boxes for the cross-head end (small end). This will give the student a clearer idea of the shape of these boxes than can be shown on an assembly drawing.

Fig. 119 shows how the rod tapers from the cross-head end of the crank end. It also shows a revolved section of the rod.



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